Multiplexing Tri-Axis Accelerometer Outputs

Introduction

A Kionix tri-axis accelerometer with analog outputs provides three output voltages (Xout, Yout, Zout) which are proportional to the respective accelerations in those directions. However, with three analog outputs to digitize, it is possible that the system microprocessor does not have the necessary A-D converters. One solution is to use the internal multiplexing capability of several Kionix accelerometer products to multiplex the three outputs to one analog signal. Another solution is to use an off the shelf multiplexer to multiplex the three outputs of the tri-axis accelerometer to one analog signal.

By multiplexing, only one A-D channel is required and the system will maintain the performance of the analog output at a high data sampling rate. Even when multiplexing all three accelerometer outputs, the maximum data sampling rate is still gated by the speed of the system microprocessor's A-D converter. This application note recommends two Texas Instruments multiplexers, CD74HCT4051 and SN74CBTLV3253, and provides technical information on how to use the internal multiplexer of several Kionix products.

Using the Internal Multiplexer

The KXPA4 features an integrated 3-channel multiplexer. The KXPB5, KXP94, and KXR94 feature an integrated 4-channel multiplexer. This feature reduces system MCU requirements to only 1 ADC and 2 digital I/O's.

Multiplexer Data Select

The KXPA4, KXPB5, KXP94, and KXR94 use two select (S0, S1) inputs to control the data flow from Vmux. When a microprocessor toggles the select inputs, the desired output is attained based on the select table. Note that logic 0 is GND and logic 1 is Vdd.

KXPA4 Output Select		
S1	**S0**	**Vmux**
0	0	X Output
0	1	Z Output
1	0	Y Output
1	1	Y Output

KXPB5 Output Select		
S1	**S0**	**Vmux**
0	0	X Output
0	1	Y Output
1	0	Z Output
1	1	Aux. In

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KXP94 Output Select		
S1	**S0**	**Vmux**
0	0	X Output
0	1	Z Output
1	0	Y Output
1	1	Aux. In

KXR94 Output Select		
S1	**S0**	**Vmux**
0	0	X Output
0	1	Z Output
1	0	Y Output
1	1	Aux. In

The following schematic shows a KXPB5 (U1) connected to a generic microcontroller (U2).

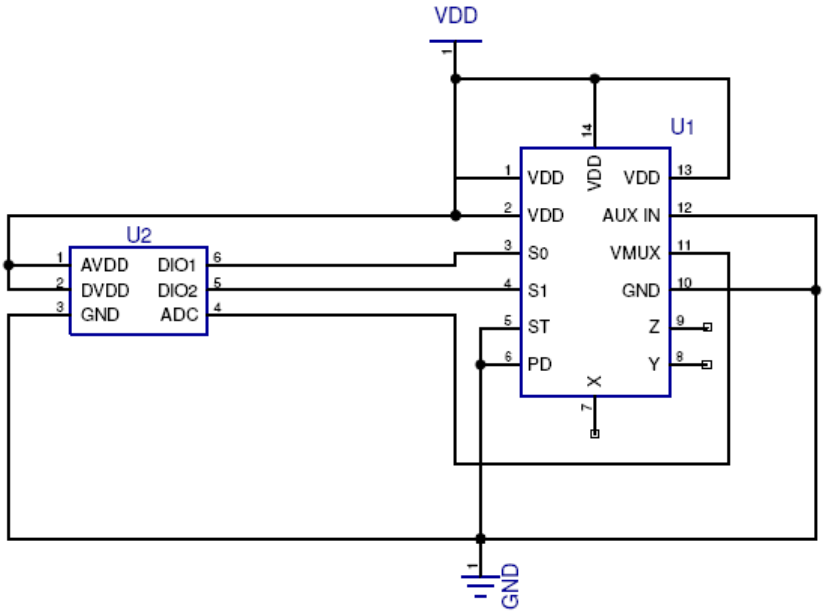

Figure 1: KXPB5 connection to a microcontroller

Two digital I/O lines (DIO1 and DIO2) are connected to S0 and S1 of the KXPB5 to control the switching of the multiplexer. The analog output of the KXPB5 (Vmux) is connected to one analog to digital converter (ADC) input of the microcontroller. The remaining connections to ground or Vdd are all that are needed to make the KXPB5 function.

Data Sampling Rate

When operating in their multiplexed mode, these parts have the ability to achieve very high data sampling rates. Internally, the sensor elements (X, Y, and Z) 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 3 separate analog outputs. This is more than sufficient to eliminate any aliasing in the final application since the Kionix accelerometer will be operating with a typical bandwidth of ~50Hz and a maximum of 2500Hz.

Using an External Multiplexer

The KXPC4 is a Kionix tri-axis accelerometer with analog outputs which does not have an internal multiplexer. If multiplexing of the outputs is desired for the application, then an external multiplexer can be used. Kionix recommends using one of two Texas Instruments multiplexers, the CD74HCT4051 or SN74CBTLV3253. Of course, you are free to use whichever multiplexer you are most familiar with.

TI CD74HCT4051

The TI CD74HCT4051 is a 1-of-8 channel high-speed CMOS logic analog multiplexer in a 16-pin SOIC package. It controls analog voltages that may vary across the voltage supply range from V_{CC} to $V_{EE.}$ Please refer to the TI CD74HCT4051 website at http://focus.ti.com/docs/prod/folders/print/cd74hct4051.html for product summaries, power requirements, specifications, and schematics.

When multiplexing the KXPC4, only three of the eight input channels are needed. Data flow of a specified output on pin Vmux can be attained by appropriately toggling the select pins (S1, S0) with the system microprocessor. The schematic in Figure 2 shows the recommended connections to the CD74HCT4051.

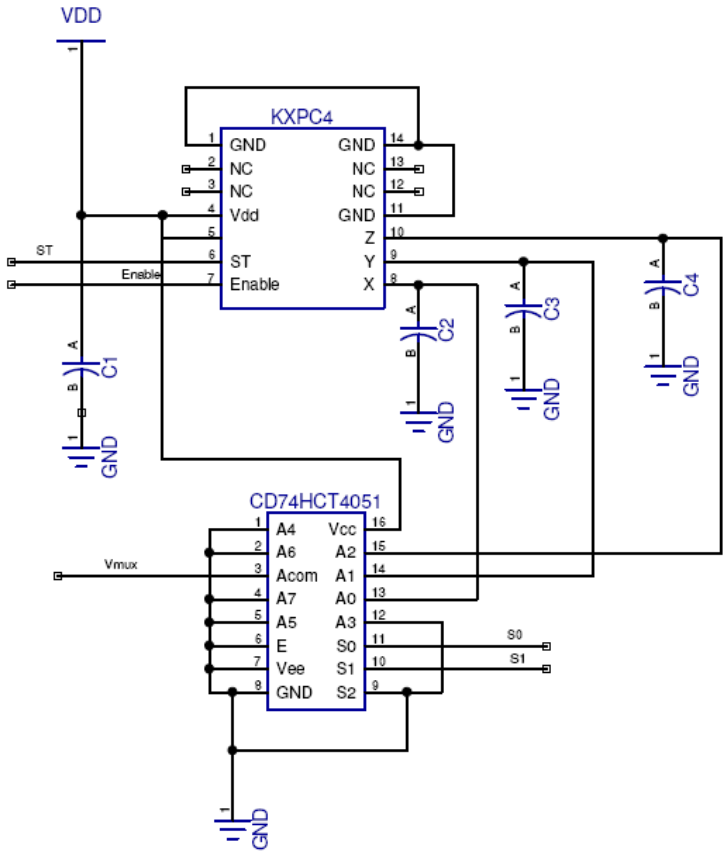

Figure 2. KXPC4/CD74HCT4051 Schematic

As previously stated, the system microprocessor will need to toggle the multiplexer select pins (S0, S1) to obtain the desired accelerometer output. The CD74HCT4051 output select table below shows the select pin inputs required to obtain a specified output.

CD74HCT4051 Output Select		
S0	**S1**	**Vmux**
0	0	Output X
0	1	Output Y
1	0	Output Z

CD74HCT4051 Output Select Table

TI SN74CBTLV3253

The TI SN74CBTLV3253 is a dual 1-of-4 channel high-speed FET analog multiplexer in a 16-pin QFN package. Please refer to the TI SN74CBTLV3253 website at http://focus.ti.com/docs/prod/folders/print/sn74cbtlv3253.html for product summaries, power requirements, specifications, and schematics.

When multiplexing the KXPC4, only three of the eight input channels and one corresponding output channel are needed. Data flow of a specified output on pin Vmux can be attained by appropriately toggling the select pins (S1, S0) with the system microprocessor. The schematic in Figure 3 shows the recommended connections to the SN74CBTLV3253.

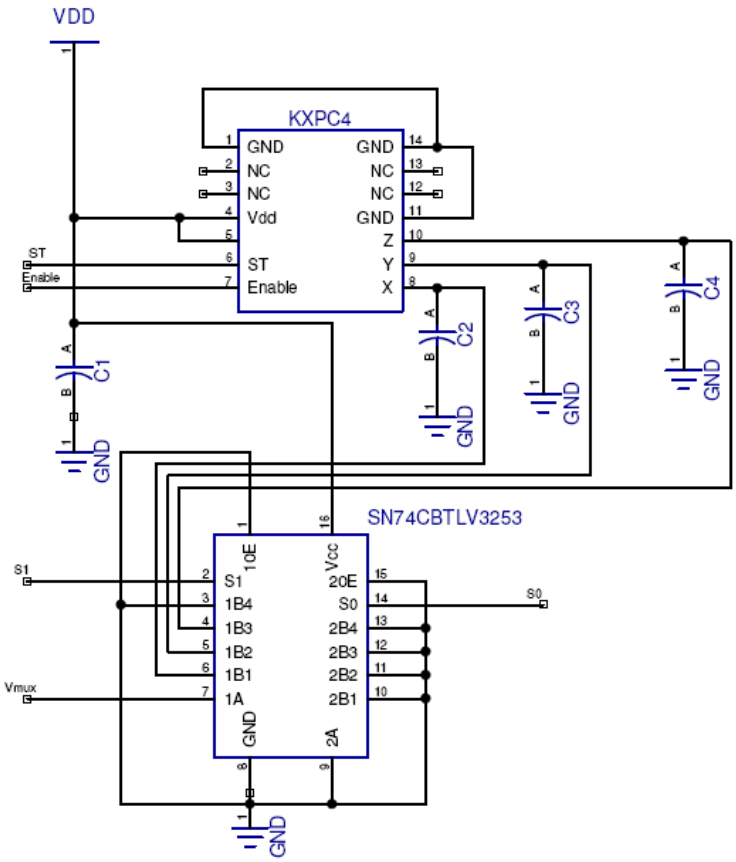

Figure 3: KXPC4/SN74CBTLV3253 Schematic

As previously stated, the system microprocessor will need to toggle the multiplexer select pins (S0, S1) to obtain the desired accelerometer output. The SN74CBTLV3253 output select table below shows the select pin inputs required to obtain a specified output.

SN74CBTLV3253 Output Select		
S0	**S1**	**Vmux**
0	0	Output X
0	1	Output Y
1	0	Output Z

SN74CBTLV3253 Output Select Table

System Sampling Rate

If the multiplexed KXPC4 is integrated with a microprocessor such as the TI MSP430F149, a maximum estimated data sampling rate can be computed. As previously stated, this sampling rate will be gated by the MSP430's A-D conversion time. With the MSP430's internal clock operating at 5MHz, this system can retrieve and convert a reading from all three accelerometer outputs in about 15.6µs. At this speed, the data sampling rate for this multiplexed KXPC4 system is approximately 64K tri-axis readings per second. This is more than sufficient for the KXPC4, which will be operating with a typical bandwidth of ~50Hz and a maximum of 3000Hz.

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. 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:

Drop force modeling for warranty management
Hard disk drive shock protection
Tilt screen navigation
Theft, man-down, accident alarm
Image stability, screen orientation
Computer pointer
Navigation, mapping
Game playing

For product summaries, specifications, and schematics, please refer to the Kionix accelerometer product sheets at http://www.kionix.com/parametric/Accelerometers