1. Introduction

The purpose of this application note is to help developers understand what can be done with the Advanced Data Path (ADP) supported by select parts in Kionix's **KX13x** family of tri-axial accelerometers. The ADP is a combination of user tailorable frequency filters and a root mean square (RMS) calculator that provides the amplitude of acceleration within a desired bandwidth. The 16-bit ADP outputs for X, Y, and Z axes can be read out from the dedicated output registers, stored in the 512-byte FIFO buffer, and be routed to the Wake-Up and Back-to-Sleep engines. By setting desirable threshold amplitude and counter value, interrupts can be generated for specific motions, rotations, or vibrations. Two simple example cases are introduced to provide an intuitive image of the advantage of this new function.

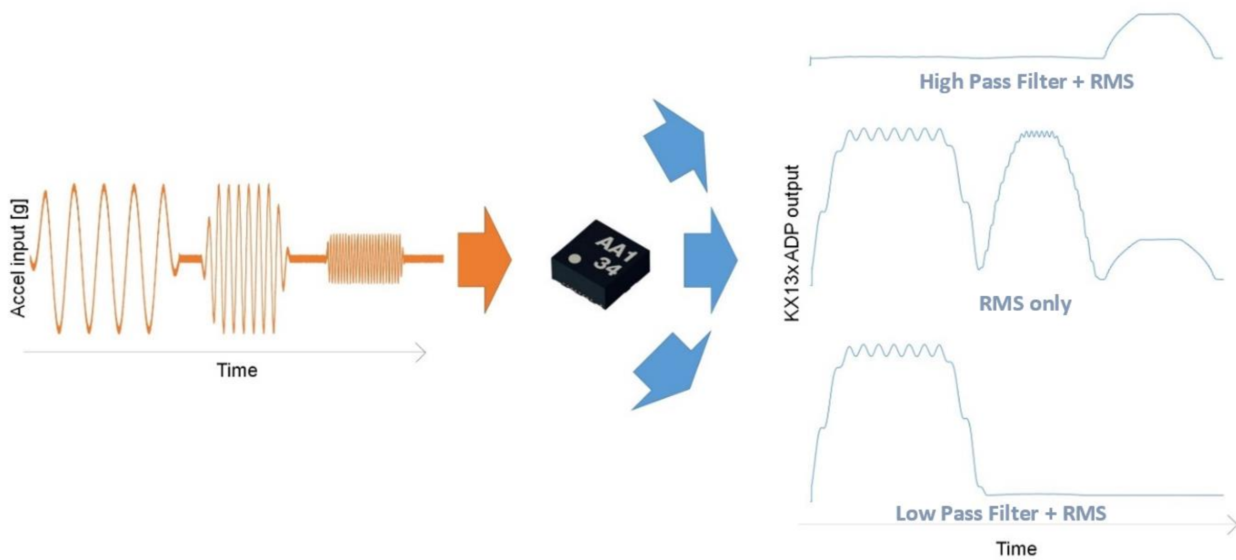

Figure 1: Example of the Advanced Data Path (ADP) Operation

Acceleration information in the real world comprised of a mixture of different frequencies and amplitudes (left) is captured by the KX13x's ADP, which can output acceleration amplitude within a specified frequency range (a variety of examples are shown on the right).

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2. Dataflow

A general data flow is described in Figure 2. A Conventional Data Path or CDP of a digital accelerometer is the first block at the top of the figure. It consists of an analog input from the MEMS, an Analog Front End (AFE) that amplifies the signal, an Analog-to-Digital Converter (ADC) for digitizing, and a Digital Signal Processing (DSP) unit for further processing. The Advanced Data Path (ADP) contains a pair of highly configurable digital filters that can be used as a combined low-pass and high-pass filter set and a root mean square (RMS) engine that calculates real time amplitude. The ADP filter settings are user accessible and are quite flexible. It can be tailored as Butterworth, Bessel, Chebyshev, or even as customized filters. The output of ADP can be stored in the dedicated output registers and/or routed to embedded 512-byte FIFO buffer. Additionally, the ADP output can be routed as an input to the embedded motion Wake-Up and Back-to-Sleep engines with configurable threshold and flexible counter to further qualify the signal. If the signal input criteria is met, an interrupt-generator will generate a physical interrupt for a host processor as well as set the corresponding status register. The Figure 2 shows an example case of generating an interrupt when detecting a condition of a “specific vibration sustained for T_h period”.

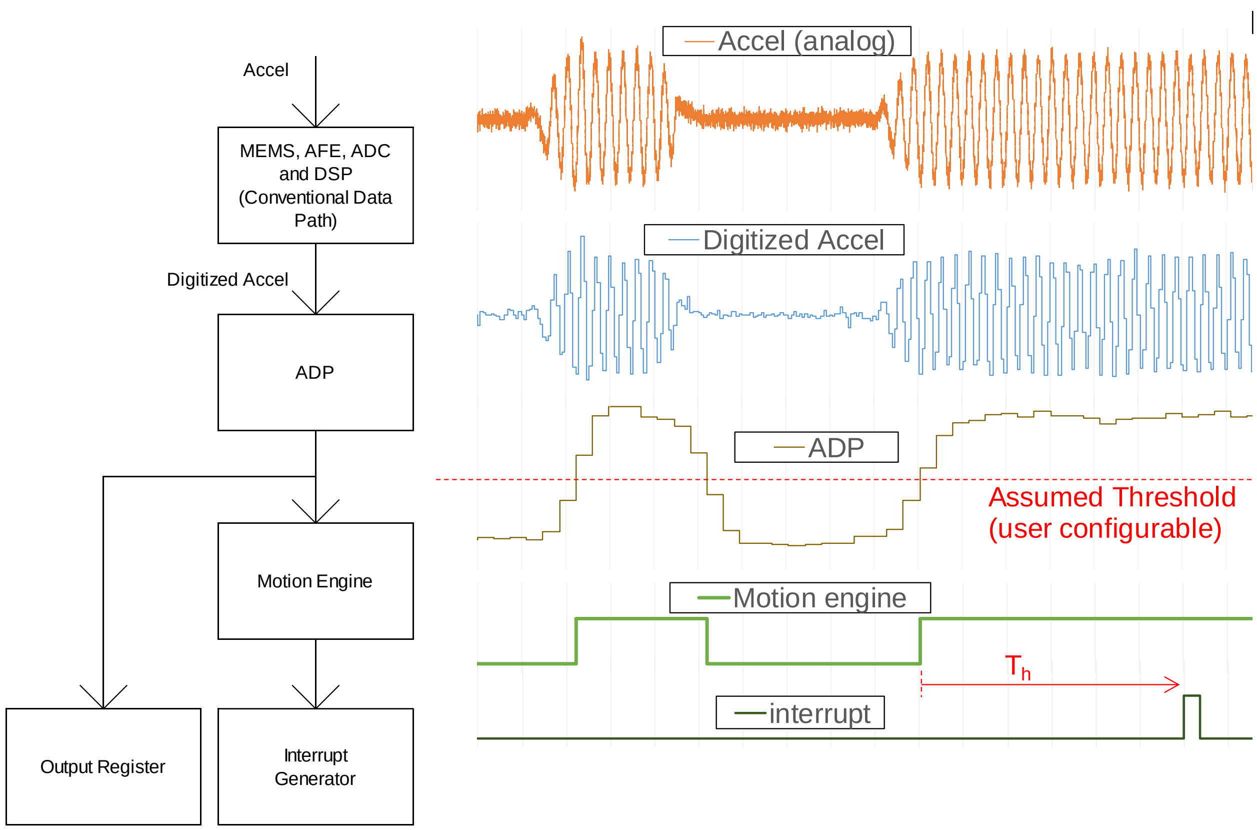

Figure 2: ADP dataflow

3. Application Examples

3.1. Machine Health

Assume f_{op} as the operational frequency of a mechanical system such as a rotating motor, and f_e as the error/failure mode frequency of the system (Figure 3). In this case, f_e is lower than f_{op} and super positioned on to it, say the motor is slowly vibrating because of loosening anchorage to its frame. Frequency analysis by MCU/DSP would be needed to detect such a defective mode with a conventional accelerometer. This would result in memory space needs as well as higher power consumption as MCU/DSP would need to remain awake.

The KX13x's ADP will detect the event with the accelerometer alone and be able to generate an interrupt for the host MCU by setting the ADP digital filter as either a band-pass or low-pass which passes f_e and eliminates f_{op}.

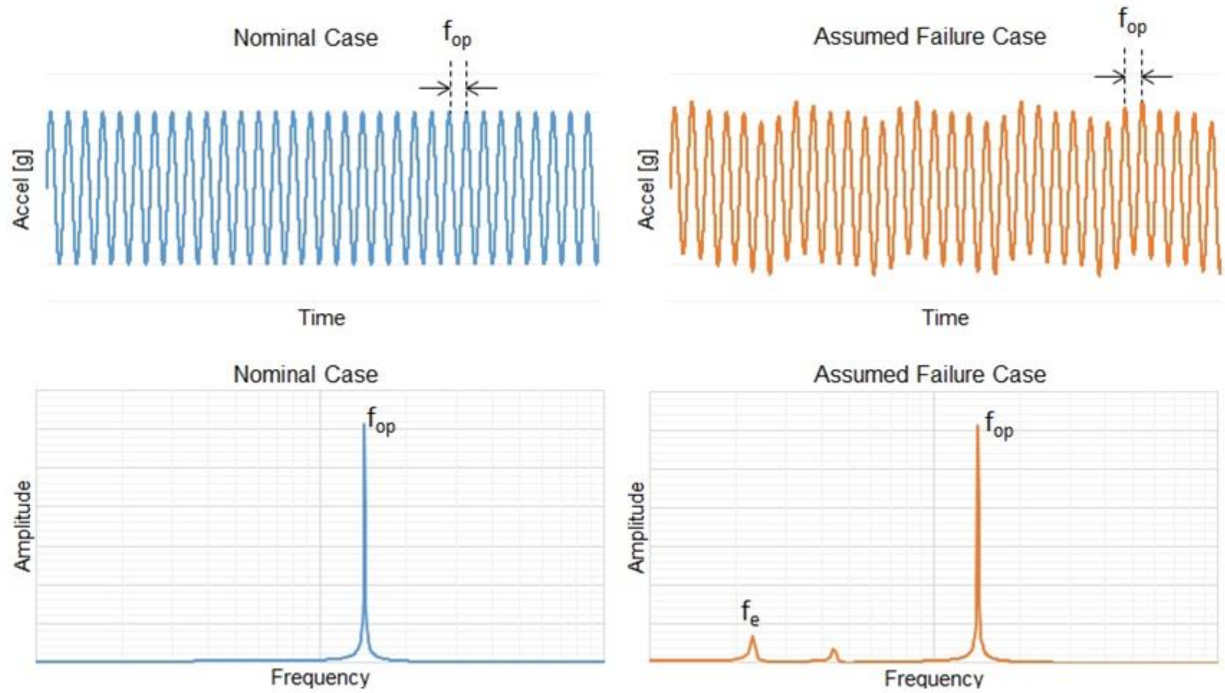

Figure 3: Frequency analysis of a normal and defective system behavior

In the Figure 4, note how the ADP is being configured as a low-pass filter to eliminate f_{op}, and RMS calculation engine is configured to achieve the absolute value of the desired defective mode signal. The signal threshold in the motion engine (mid waveform) is used to qualify the event. Finally, the bottom waveform shows the true signal generated by the motion engine. When event is detected, the WUFS bit would be set in INS3 register and the interrupt will be asserted on the external interrupt pin (if configured).

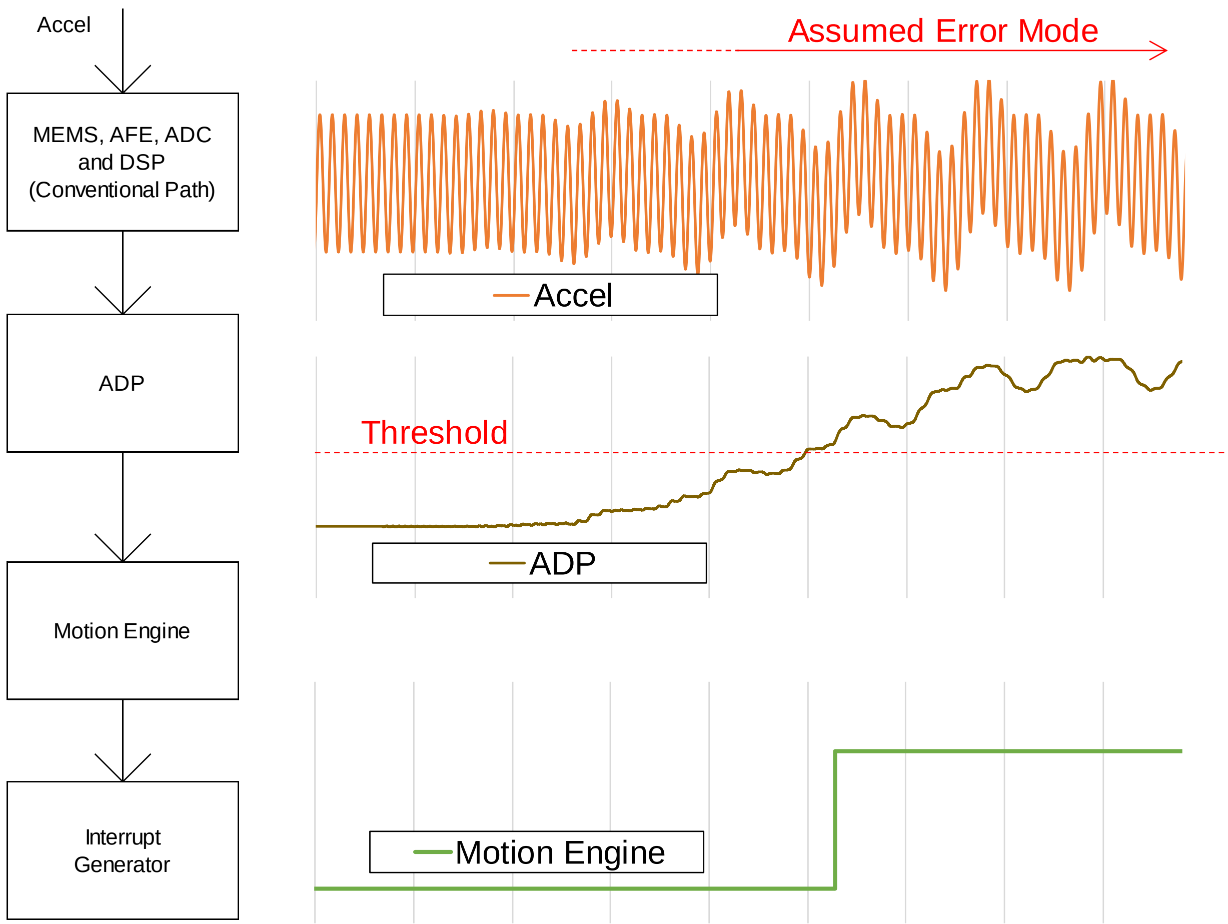

Figure 4: ADP isolates target signal from raw accel data and passes amplitude information to motion engine

3.2. Envelope Analysis

Envelope analysis is an efficient approach for failure detection of periodic vibrations such as the failure of an antifriction-bearing. The ADP can be used for generating the envelope (*1) of acceleration data. A fast Fourier transform (FFT) of the envelope waveform shows period of vibration which helps identifying defective parts in the system. In this case, the ADP filter should be configured as a "band-pass" which includes both Vibration and Error frequency and excludes DC and high-frequency noise.

(*1) Note: ADP output is pseudo envelope, not Hilbert-Transformed.

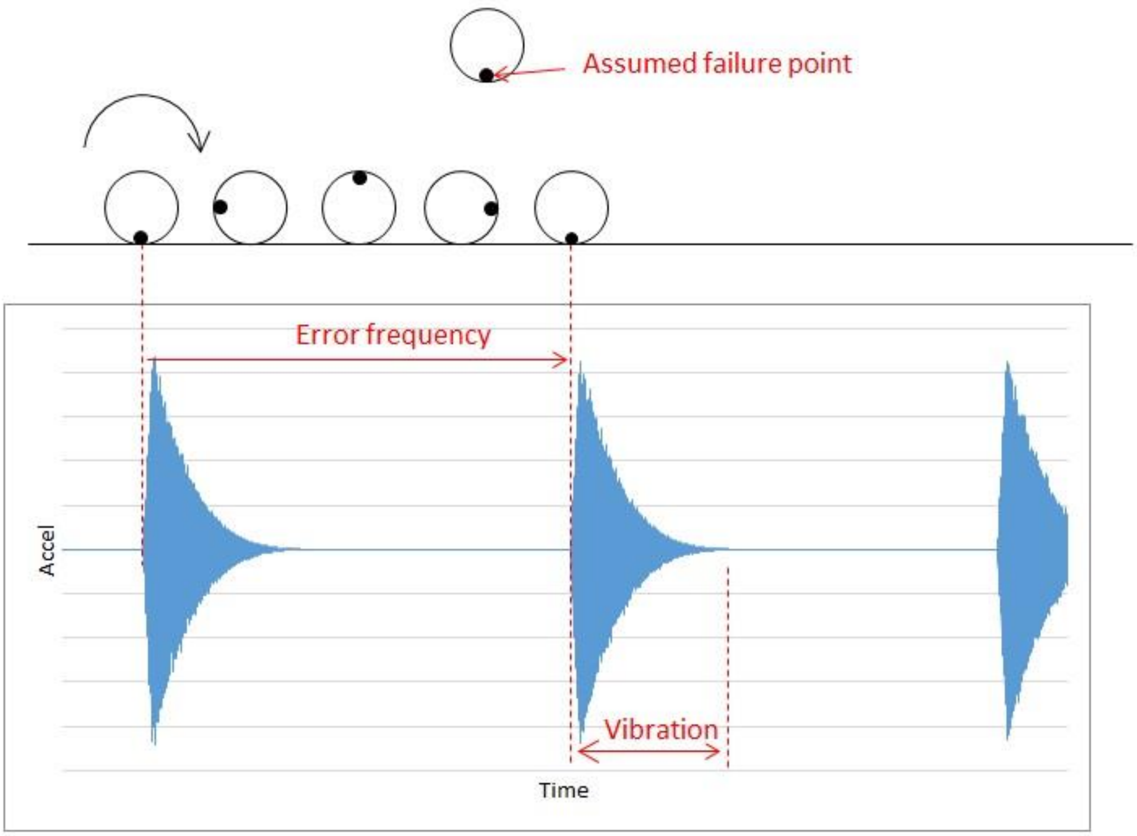

Figure 5: Periodic vibration caused by a defect on bearing sphere

The envelope waveform can be stored in the 512-byte buffer on the KX13x and be sent to host processor for FFT analysis.

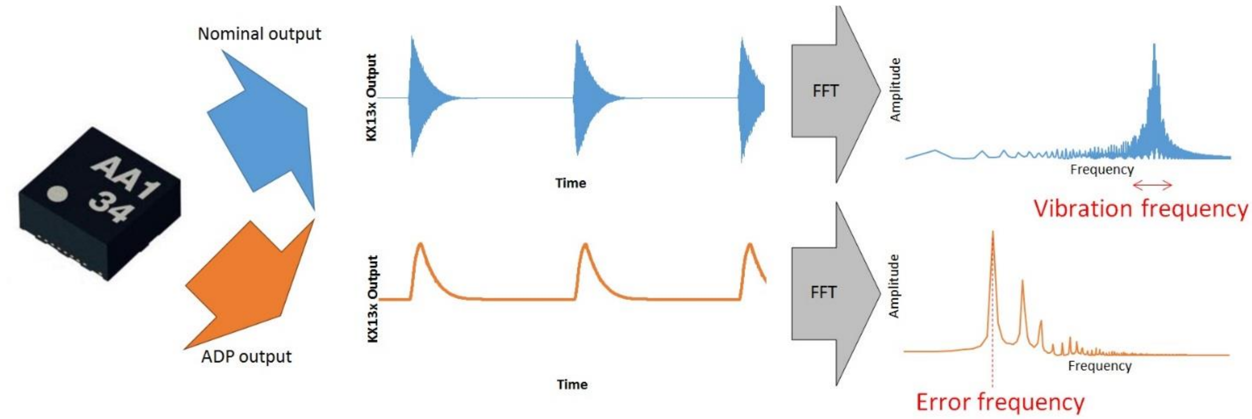

Figure 6: FFT using raw accel data and its envelop

For more detailed information and usage of the KX13x's ADP, please contact Kionix or local Rohm sales representatives.

4. Additional Resources

- KX13x Family Webpage
  https://www.kionix.com/product/KX13X