DT0155
Design tip

Synchronizing multiple sensors using ODR-triggered mode in MEMS devices

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Main components	
LSM6DSV16X	High-performance, low-power 6-axis IMU with embedded sensor fusion, AI, Qvar for high-end applications
LSM6DSV	6-axis inertial measurement unit (IMU) with embedded sensor fusion, I3C, OIS/EIS for smart applications
X-NUCLEO-IKS4A1	Motion MEMS and environmental sensor expansion board for STM32 Nucleo

Purpose and benefits

This design tip explains how to set up the ODR-triggered mode and its behavior in MEMS sensors. Using this mode allows multisensor measurement. The benefits of this mode are:

- Synchronizing multiple sensors to one reference signal
- Automatic frequency and phase alignment to the edges of the reference signal

Introduction

Every device has its own ODR frequency (slightly different due to natural spreads). The LSM6DSV16X device provides a way to synchronize its data generation with an external hardware reference signal provided over the INT2 pin. The device is able to automatically align the frequency and phase to the edges of the reference signal.

Figure 1. ODR-triggered mode

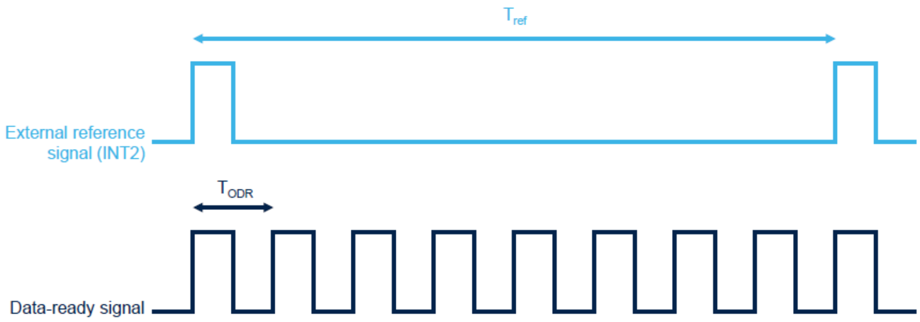


Figure 1 shows how the sensor aligns its DRDY signal to an external reference using ODR-triggered mode.

ODR-triggered mode supports the following modes: accelerometer only, gyroscope only, and combo (accelerometer and gyroscope).

When using a single-sensor configuration, either an accelerometer or gyroscope, the unused sensor must be powered down. For combo configuration, it is necessary to set both sensors either in ODR-triggered mode or in power-down. In a combination, it is crucial that both sensors possess an identical ODR value. If the user configures different values, the gyroscope value is utilized for both sensors. Table 1 shows several variations of possible sensor settings.

Sensor-desired ODR_{sel} and the number of samples can be chosen from Table 1. These two variables determine the required frequency of the reference signal.

$$\frac{ODRsel}{samples} = reference\ signal\ frequency$$

Table 1. ODR-triggered mode configurability

ODR_XL_[3:0] / ODR_G_[3:0]	ODR_{sel} [Hz]	$\frac{T_{ref}}{T_{ODR}}$ minimum ratio [# samples]	Minimum T_{ref} period [ms]
0011	12.5	8	640
0100	25	8	320
0101	50	8	160
0110	100	8	80
0111	200	8	40
1000	400	16	40
1001	800	32	40
1010	1600	64	40
1011	3200	128	40

Note: ODR_XL_[3:0]/ODR_G_[3:0] is from the register CTRL1/CTRL2 bit configuration. ODR_{sel} is the desired output data-ready signal frequency. The number of samples is set as a ratio of the reference signal period T_{ref} and ODR_{sel} period, T_{ODR}.

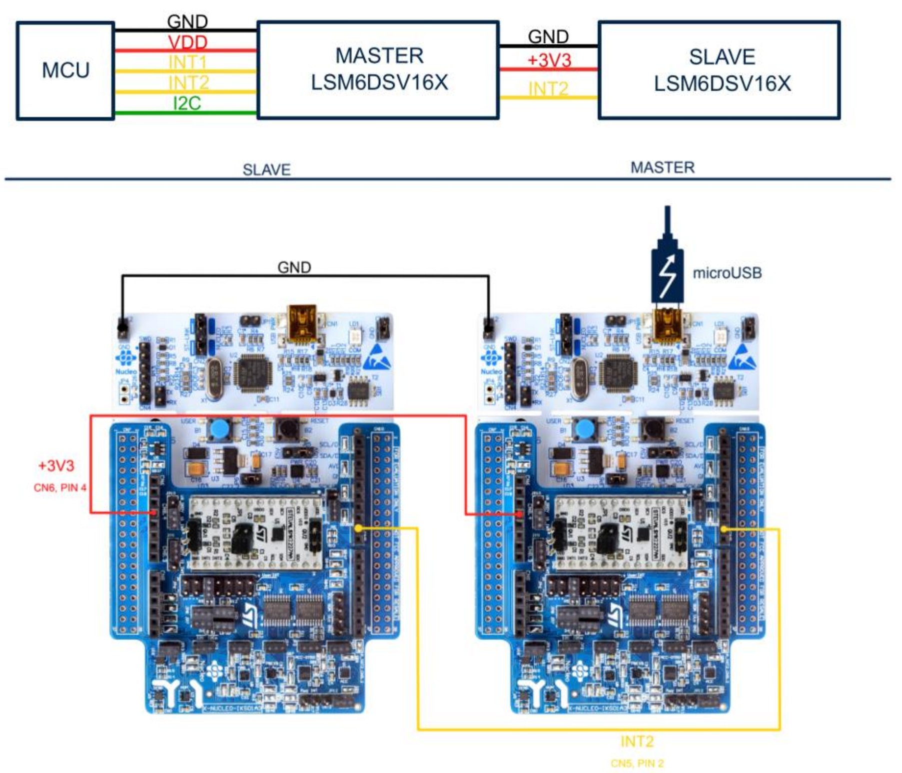
For more details, refer to Section 3.3 in application note AN5763, 6-axis IMU with embedded sensor fusion, AI, Qvar for high-end applications

Configuration example with two sensors

This example shows the capability of ODR-triggered mode to align data measurements with an external reference signal using two sensors. We used the LSM6DSV16X sensor.

In this case, a PWM signal is used as the source of the external signal. Its frequency is set to 12.5 Hz, accelerometer output data-ready is set to 100 Hz, 8 samples per period, sensitive to the rising edge.

Figure 2. Block diagram and wiring diagram

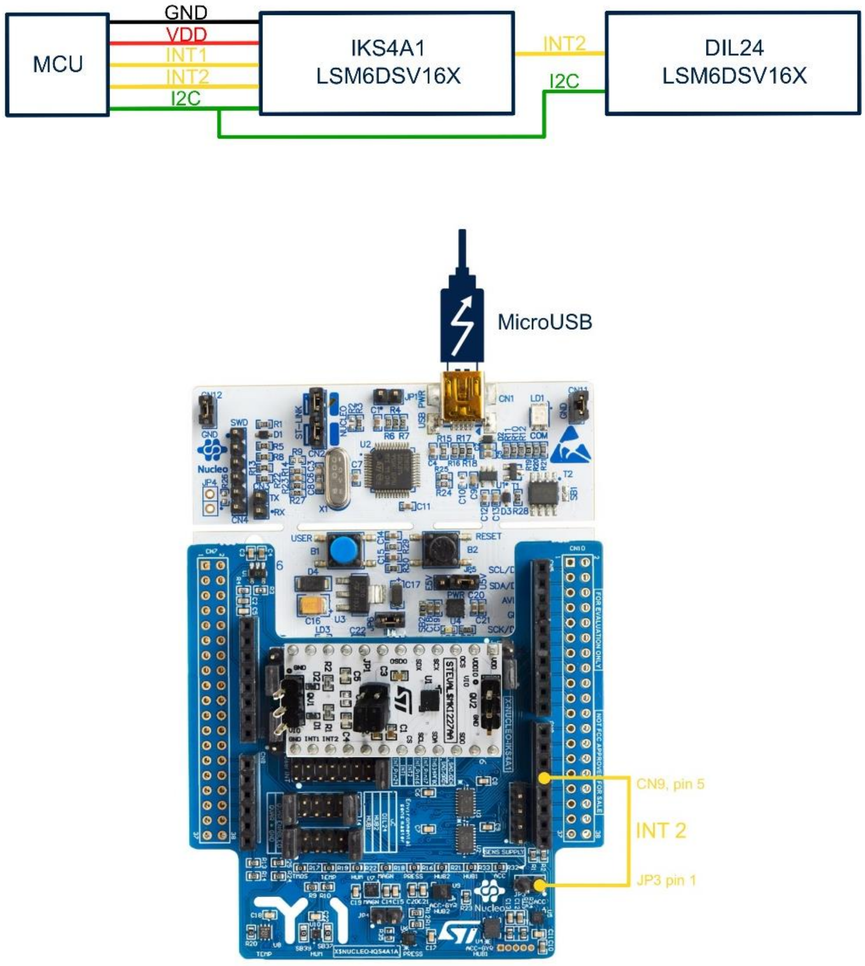


Boards: NUCLEO-F401RE, X-NUCLEO-IKS01A3, STEVAL-MKI227KA

Dual-sensor configuration for the X-NUCLEO-IKS4A1 expansion board

The X-NUCLEO-IKS4A1 expansion board can be utilized for a dual-sensor configuration. The board comes with an LSM6DSV16X sensor already integrated, which greatly minimizes the hardware requirements for implementation.

Figure 3. Block diagram and wiring diagram



Boards: NUCLEO-F401RE, X-NUCLEO-IKS4A1, STEVAL-MKI227KA

To generate the PWM signal, the user must configure the MCU timer. The timer's source was set to the internal clock, Channel# was set to PWM Generation CH#. To obtain the desired PWM frequency, it is necessary to calculate the values of the prescaler and the counter period.

Note: For counter period calculations, the following formula was used, where HCLK is the MCU frequency and the prescaler is chosen by the user.

$$timclk = \frac{HCLK}{prescaler} \; , \; counter\ period = \frac{timclk}{ODRsel}$$

The register settings of the LSM6DSV16X used in this example are as follows:

```
1. Write 01h to CTRL1 register          //Set accelerometer in power-down mode
2. Write 04h to ODR_TRIG_CFG register   //Configure 8 samples per each Tred period
3. Write 30h to CTRL1 register          //Set accelerometer in ODR-triggered mode
4. Write 01h to CTRL4 register          //ODR-triggered mode sensitive to rising edge
5. Write 36h to CTRL1 register          //Set accelerometer ODRsel 100 Hz
6. Write 01h to INT1_CTRL register      //Enable INT1 pin
7. Write 03h to CTRL4 register          //Enable pulsed DRDY mode, and INT2 as input
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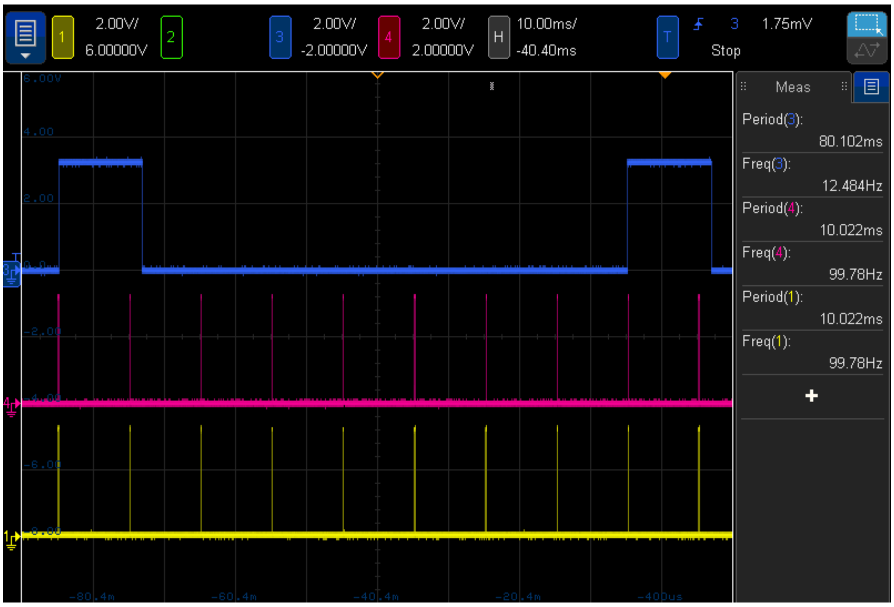
Figure 4 shows the output of the example where both sensors are aligned as they should be. The blue signal waveform is PWM and the yellow and pink waveforms are the data-ready interrupt signals.

Figure 4. Example output



Min and max selectable ODR frequency

The selectable output date rates (ODR_{sel}) are different with respect to the regular ODRs set. The external reference signal must be provided with a period, which is an even multiple of the desired ODR period. The desired ODR period can have a maximum deviation of ±33% with respect to the selected ODR_{sel}.

The reference signal frequency 100 Hz has a negligible deviation with respect to the selected ODR configured through the ODR_XL_[3:0] bits of the CTRL1 register and the ODR_G_[3:0] bits of the CTRL2 register. The user can achieve an ODR of 100 Hz ±33% by fine-tuning the external reference signal period (T_{ref}).

The user can select ODR_{sel} in the range from a minimum of 12.5 Hz up to a maximum of 3200 Hz. According to the first paragraph, adding a deviation of ±33% spreads the range from 8.4 Hz to 4256 Hz.

Figure 5 and Figure 6 show both minimum and maximum usable ODR frequencies.

Figure 5. Minimum ODR frequency (12.5 Hz -33% deviation)

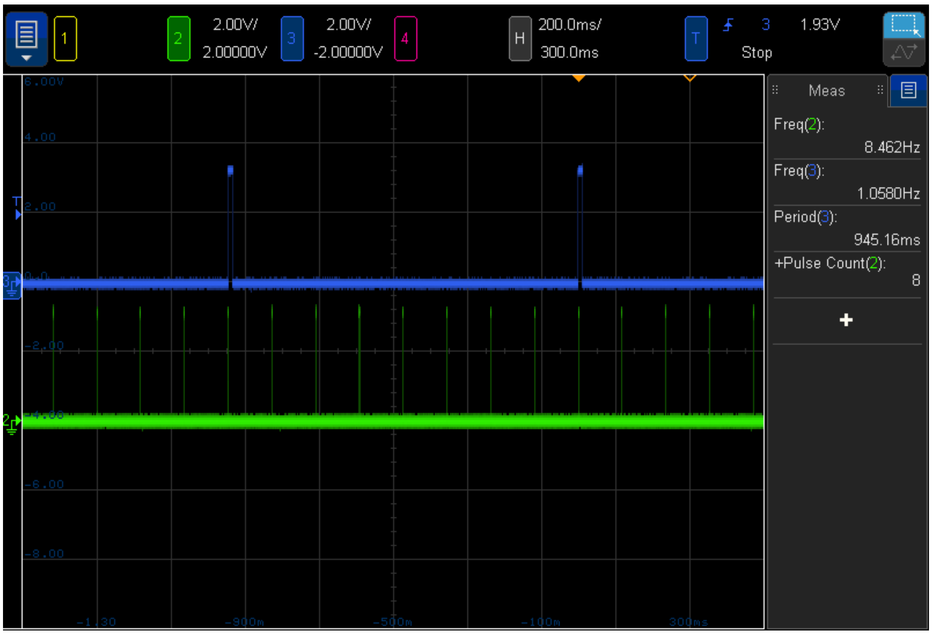
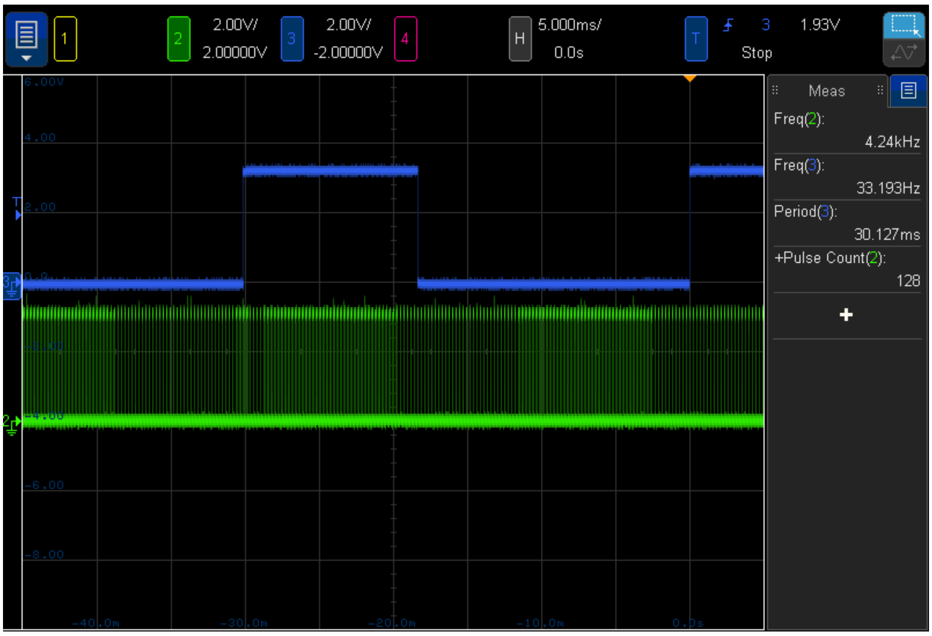


Figure 6. Maximum ODR frequency (3200 Hz +33% deviation)



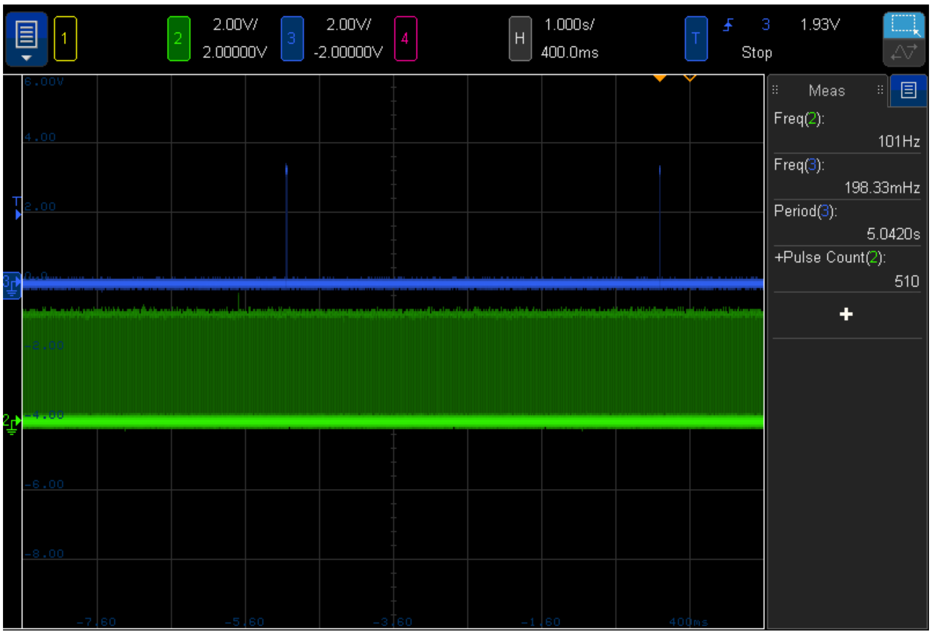
Note: Shown measurements are taken between the blue peaks, triggered to a rising edge.

Desired number of samples in one period

The desired number of samples in one external reference signal period must be configured through the ODR_TRIG_N_ODR_[7:0] bits of the ODR_TRIG_CFG register. The value of the ODR_TRIG_N_ODR_[7:0] bits can span from a minimum of 4 to a maximum of 255 and its resolution is 2 samples (therefore, from a minimum of 8 samples to a maximum of 510 samples). The ODR_{sel} set available for ODR-triggered mode, the corresponding minimum number of samples for each ODR, and the corresponding minimum period for the external reference signal are indicated in Table 1.

In Figure 7, you can see our example reconfigured to maximize the T_{REF}/T_{ODR} ratio, which means 510 samples per period.

Figure 7. 100 Hz ODR frequency, 510 samples per period



Note: Shown measurements are taken between the blue peaks.

Current consumption

Typical current consumption values can be found in application note AN5763, Section 3.4. Table 2 indicates the measured current consumption for the Configuration example with two sensors.

Table 2. Current consumption while ODR-triggered mode is active (ODR = 100 Hz)

Mode	Current consumption [µA]
Accelerometer only	430
Accelerometer + Gyroscope	670

Note: Results are not guaranteed, the measurement has been taken with a limited number of sensors.

Real-life example

This example shows the difference between synchronous and asynchronous sensors. Synchronous sensors are configured in ODR-triggered mode as shown in Configuration example with two sensors. Both of the asynchronous sensors are configured in high-performance mode with the accelerometer ODR set to 100 Hz.

Figure 8 illustrates the generated sine wave that we are measuring. The sine was generated by a shaker. DRDY is read every period from both sensors. If we synchronize the sensors and read data with the same ODR as the sine frequency, we should theoretically get values around 0 amplitude – in the case with the accelerometer 1000 m*g*. The ODR is intentionally set to the frequency of the sine wave to ensure that data is collected at the end of each period.

Figure 8. Measured sine signal

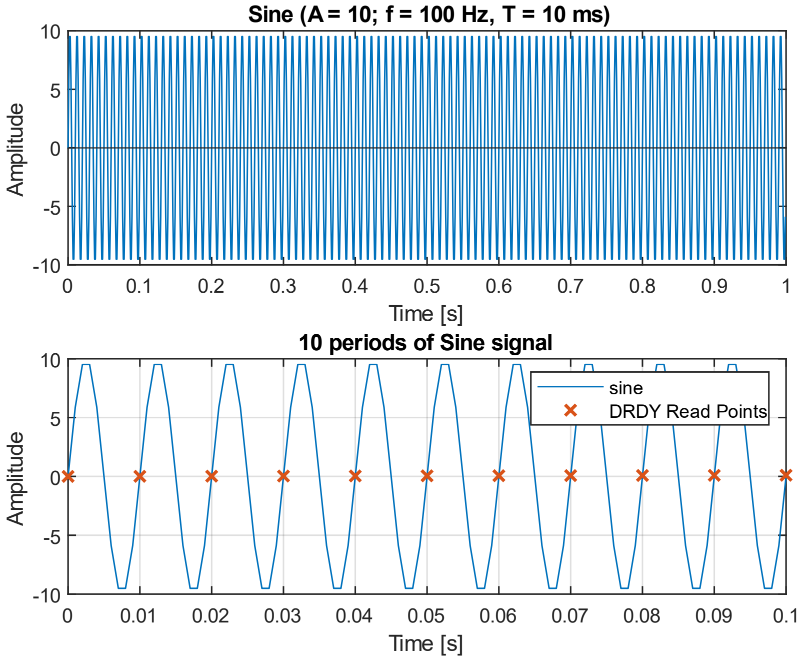


Figure 9 shows DRDY from both sensors without any synchronization while Figure 10 shows DRDY from both master and slave sensors in ODR-triggered mode.

Figure 9. DRDY output from master and slave without ODR-triggered mode

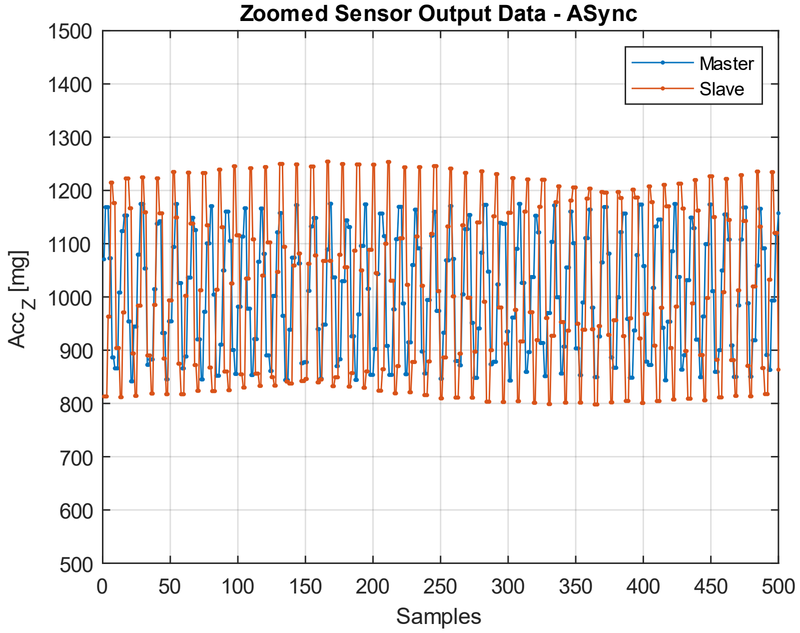
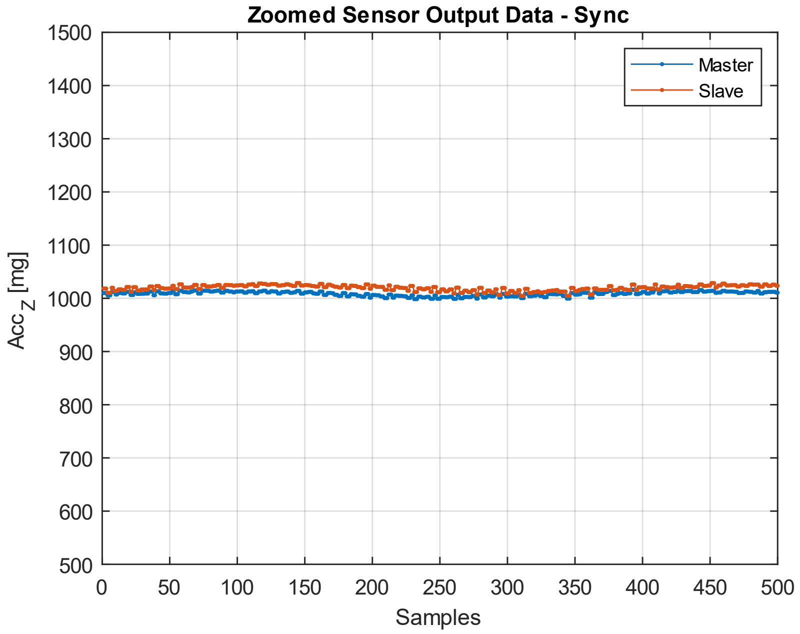


Figure 10. DRDY output from both sensors in ODR-triggered mode



Note: The position of the slave on the example board may cause a slight shift in its phase.

Figure 11. DRDY output when one sensor synchronous and second asynchronous

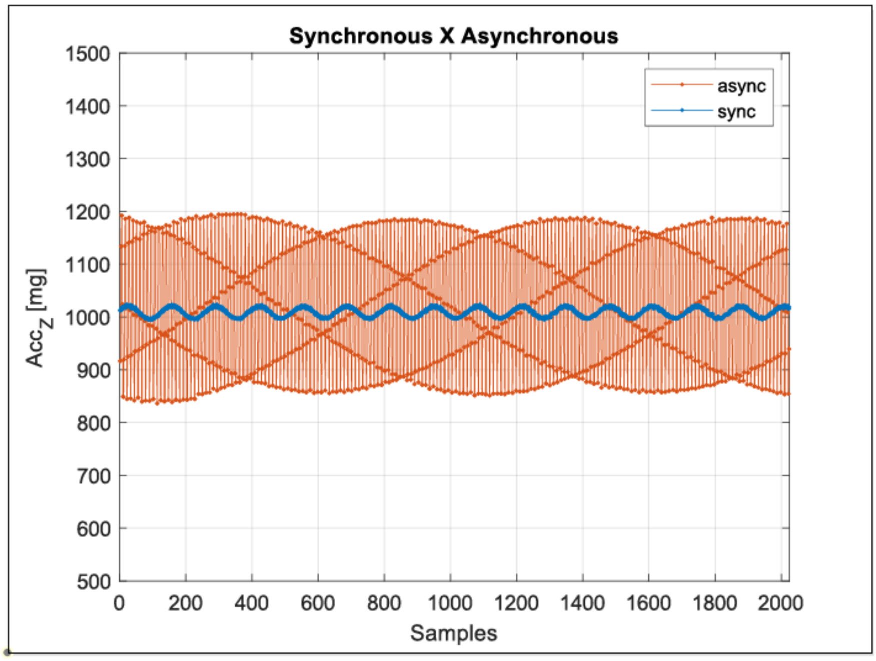


Figure 11 illustrates the difference between synchronous and asynchronous sensors. The amplitude of the synchronous sensor is significantly closer to 1000 m*g* compared to the asynchronous sensor. For the asynchronous sensor, we can see severe aliasing.

Figure 12. Shaker used for measurement

Support material

Documentation
Ref. 1 – LSM6DSV16X: datasheet, 6-axis inertial measurement unit (IMU) and AI sensor with embedded sensor fusion, Qvar for high-end applications
Ref. 2 – LSM6DSV16X: application note, AN5763, 6-axis IMU with embedded sensor fusion, AI, Qvar for high-end applications
Ref. 3 – X-NUCLEO-IKS4A1: data brief, user manual UM3239, Getting started with the X-NUCLEO-IKS4A1 motion MEMS and environmental sensor expansion board for STM32 Nucleo

Revision history

Date	Version	Changes
04-Jan-2024	1	Initial release
07-Feb-2024	2	Added Dual-sensor configuration for the X-NUCLEO-IKS4A1 board