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Design tip

Low-power application design with ST's MEMS accelerometers

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Main components	
LIS2DW12	MEMS digital output motion sensor: high-performance ultra-low-power 3-axis "femto" accelerometer

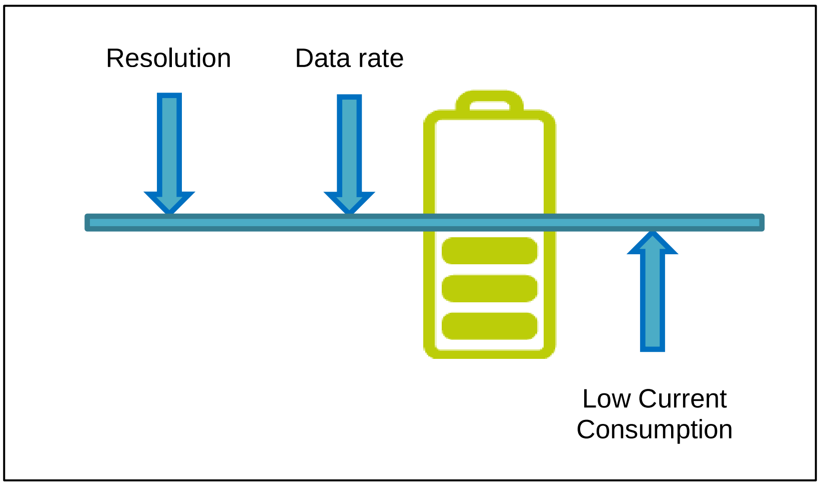
Purpose and benefits

This design tip explains how to utilize features of ST's MEMS accelerometers, and in particular the LIS2DW12 device, when designing applications requiring very low power consumption. First of all, device configuration options for low-power design will be explained. Then different techniques for achieving the lowest power consumption are described, for example how to deal with power supply, utilization of the sensor's embedded features or efficient communication with the sensor.

Device configuration

Low-power applications benefit from using MEMS accelerometer sensors which increase battery life. Sensors are becoming less and less power-hungry and embed features that help to decrease overall system power consumption.

Figure 1. Sensor parameters impacting battery life



Starting from the MEMS accelerometer sensor itself, it should be flexible in its operating modes. As depicted in Figure 1. there is a well-known trade-off between a sensor's resolution and its output data rate on one side and the current consumption on the other side – the higher the resolution or the data rate, the higher the current consumption and vice versa.

The LIS2DW12 offers very high flexibility in terms of operating modes and output data rates which result in a wide range of current consumption as shown in Figure 2. The LIS2DW12 can operate in one of ten operating modes that can be changed on the fly. The user can choose the mode that is the most suitable for his application at any particular moment. This allows covering a broad range of applications. For instance, high-precision data needed for inclination measurements or alarm systems can be acquired thanks to very low output noise smaller than 1 m*g*. At the same time, applications requiring ultra-low current consumption can benefit from four low-power modes present in the sensor that allow sensing data with power consumption as little as 0.38 µA. The sensor can continuously measure acceleration data at output data rates (ODR) ranging from 1.6 Hz to 1.6 kHz. Table 1. depicts all the configuration options that the LIS2DW12 offers in terms of operating modes and ODR and, as a consequence, noise and current consumption selection.

Figure 2. Flexibility of LIS2DW12

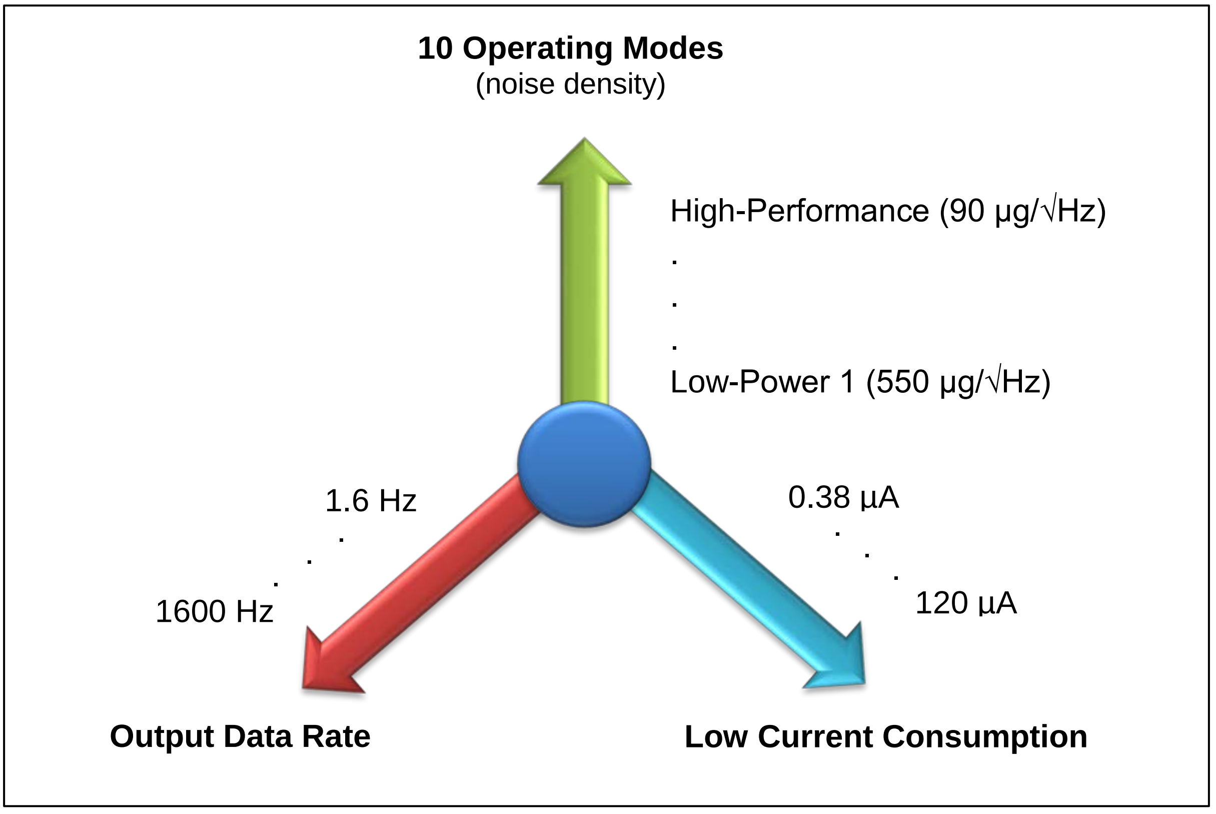


Table 1. LIS2DW12 Operating modes and ODR configurations

		High Performance Mode	Low Power Mode 4	Low Power Mode 3	Low Power Mode 2	Low Power Mode 1
Resolution [bit]		14	14	14	14	12
ODR [Hz]		12.5 - 1600	1.6 -200	1.6 - 200	1.6 - 200	1.6 - 200
Noise Density [µg/√Hz] @ FS=2 *g* , ODR=200 Hz		110 / 90	160 /130	210 / 180	300 / 240	550 / 450
Current cons [µA]	**ODR = 1.6 Hz**	-	0.65 / 0.7	0.55 / 0.6	0.45 / 0.5	0.38 / 0.4
	ODR = 12.5 Hz	90 / 120	4 / 5	2.5 / 3	1.6 / 2	1 / 1.1
	ODR = 25 Hz	90 / 120	8.5 / 10	4.5 / 6	3 / 3.5	1.5 / 2
	ODR = 50 Hz	90 / 120	16 / 20	9 / 11	5.5 / 7	3 / 3.5
	ODR = 100 Hz	90 / 120	32 / 39	17.5 / 21.5	10.5 / 13	5 / 6
	ODR = 200 Hz	90 / 120	63 / 77	34.5 / 42	20.5 / 25	10 / 12
	ODR = 400,1600 Hz	90 / 120	-	-	-	-

Low noise disabled / enabled

Single data conversion

The LIS2DW12 provides even higher flexibility in selecting data sampling rates. Besides automatic data sampling, single data conversion based on an external trigger is available. In this mode measurements are started either on the trigger signal routed to the INT2 pin of the LIS2DW12 or by a register write transaction initiated from the microcontroller (MCU) using a serial command. Data acquired in this way are then stored either in the output data registers or in the internal FIFO buffer. The sensor can also initiate an interrupt signal informing the MCU that data conversion has been completed and that data is now available to be read by the application. Thanks to this feature, data rates smaller than 1 Hz or basically any other rate (up to 200 Hz) besides the predefined ones are achievable and easily synchronized with an external sensor.

Power supply management

Another useful design practice is to utilize a low-power supply level which also means lower current consumption. That’s why for low-power applications, a 1.8 V power supply is preferred.

In some designs power cycling of the sensor can be used. The sensor’s power supply is activated only when motion data are supposed to be measured, otherwise the sensor is powered off.

Embedded features

The majority of MEMS accelerometers including the LIS2DW12 are digital sensors, which means that they internally convert measured analog signals to digital data. A shorter bill of materials thanks to an integrated AD convertor and lower susceptibility to signal distortions are not the only advantages. Thanks to embedded interrupt generators, MEMS accelerometers can generate a trigger signal when certain user-parametrized conditions are met. This is where motion-activated wakeup comes from. The MCU configures the sensor to generate a wakeup trigger and goes itself into a very low-power sleep mode. When motion is detected, the sensor will generate an interrupt signal, the MCU receives the signal, switches into an appropriate operating mode and finally handles the situation that has occurred.

Digital sensors can also take over tasks related to motion processing normally done by the MCU. The MCU could do the same job of course, but with worse power efficiency – the MCU operating in milli amps range while the sensor in micro amps range. Detection of movements like free-fall, single and double-tap (user actions similar to a mouse click), portrait / landscape orientation detection and others are processed by the internal logic of the sensor. The MCU does not need to make any computations, it simply waits for an interrupt trigger and reacts to the movement only when it occurs.

The LIS2DW12 is equipped with a rich set of embedded digital features like: tap / double-tap recognition, wakeup detection, free-fall detection, 6D / 4D orientation, portrait / landscape detection and activity / inactivity function. These are features which can be seen also in other digital MEMS accelerometers. However the LIS2DW12 brings a well-balanced set of parameters to users that can be fine-tuned according to particular application needs. For example the tap / double-tap recognition feature that allows detecting motions similar to mouse clicks has a configurable number of axes used for detection. It is possible to set priorities of axes and independent thresholds for each axis. This feature helps to adjust properly tap recognition to different sensor positions and application scenarios.

The LIS2DW12 sensor also integrates signal filters which condition just-measured acceleration data. These consist of low-pass, high-pass and anti-aliasing filters that pre-process data for the MCU and offload it even more.

In applications where the MCU is loaded with many tasks or when current consumption is a key parameter, the FIFO buffer embedded in the LIS2DW12 provides the possibility to store up to 32 data samples coming from all 3 axes in full resolution. The FIFO buffer has a number of operating modes. The FIFO buffer serves a useful function in that it stores the history of motion events detected by the sensor – this can be, for example, a shock or free-fall. This allows the MCU to be able do other tasks, stay longer in sleep and also save time needed for serial communication with the sensor.

Communication with the sensor

Serial communication between the sensor and the MCU contributes to overall power consumption as well. For very low-power applications dealing with every micro amp, serial communication could have a significant impact. The LIS2DW12 MEMS accelerometer communicates either over SPI or I²C interfaces. The SPI interface is more efficient in terms of power consumption for three reasons: first, there are no pull-ups on communication lines causing extra current consumption, second, it supports higher data rates and third, it has less overhead in its serial protocol.

Regardless of the interface, significant reduction of serial communication can be achieved if, instead of polling the sensor, i.e. continuously asking for the status of new data availability, rather the application utilizes the data-ready interrupt. The data-ready interrupt is automatically generated by the sensor when it has finished data measurement and conversion and a new set of data is ready to be read by the MCU. When this interrupt is activated, the MCU can immediately read output data from the sensor in one single read operation.

Conclusion

We have discussed features of an accelerometer sensor that are important for low-power applications and also ways of utilizing them in system design. The LIS2DW12 brings flexibility in designing new applications thanks to its very low current consumption down to 1 µA, number of operating modes, wide range of output data rates, rich set of embedded digital features and enhanced functionalities like digital filters and the FIFO buffer. In highlighting these features we have illustrated the benefits and advantages of implementing the LIS2DW12 in low-power applications using motion-activated functions and user interfaces, smart power saving for handheld devices, motion detection for appliances and impact recognition logging for wireless sensor nodes.

Support material

Related design support material
Product Evaluation board – STEVAL-MKI179V1, LIS2DW12 adapter board for a standard DIL 24 socket
Documentation
Datasheet LIS2DW12, High-performance ultra-low-power 3-axis "femto" accelerometer
Application note AN5038, LIS2DW12: MEMS digital output motion sensor ultra-low-power high-performance 3-axis "nano" accelerometer

Revision history

Date	Version	Changes
04-Feb-2019	1	Initial release