

Optimizing Magnetic Sensor Power Operations for Low Data Rates

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1 Introduction

The standard mode of operation of a magnetic sensor is not conducive to low data rate applications ($\ll 1$ Hz). These applications require a more efficient power budget. Power cycling the magnetometer achieves the lowest possible current consumption, thus extending the battery life for Internet of Things (IoT) applications.

This application note describes two measurement methods associated with reducing current consumption in low data rate applications for two Freescale magnetometers (FXOS8700 6-Axis E-Compass and MAG3110 Digital Magnetometer):

- the one-shot measurement method
- the power cycling measurement method

Based on analysis of current consumption testing, the following recommendations are presented.

NOTE: Previous documentation regarding the two devices described in this document refer to similar measurement methods using different names. For clarity, in this document, *single-shot measurement* and *one-shot measurement* are referred to as *one-shot measurement*.

2 Recommended Implementations

Freescall recommends the following to minimize power consumption:

- For applications with data rates greater than 0.5 Hz, use one-shot measurement method for the sensor.
- For applications with data rates less than 0.5 Hz, use power cycling measurement method for the sensor. Operating the sensor using this method can achieve average I_{DD} values as low as 500 nA (for data rates near 0.1 Hz).

3 One-Shot Measurement Method

3.1 General Description of One-Shot Measurement Method

The one-shot method allows the sensor to take a single measurement with a specified oversampling ratio (OSR) and then, as soon as the measurement is complete, the sensor is transitioned to standby mode. The operational flow for one-shot method is shown in Figure 1. No further measurement will occur until the sensor is reinitialized for an additional measurement. For low data rate use cases, the average current using this method is significantly lower than the sensor’s standard active mode. However, the 2 μ A standby current for the duration between measurements may be significant.

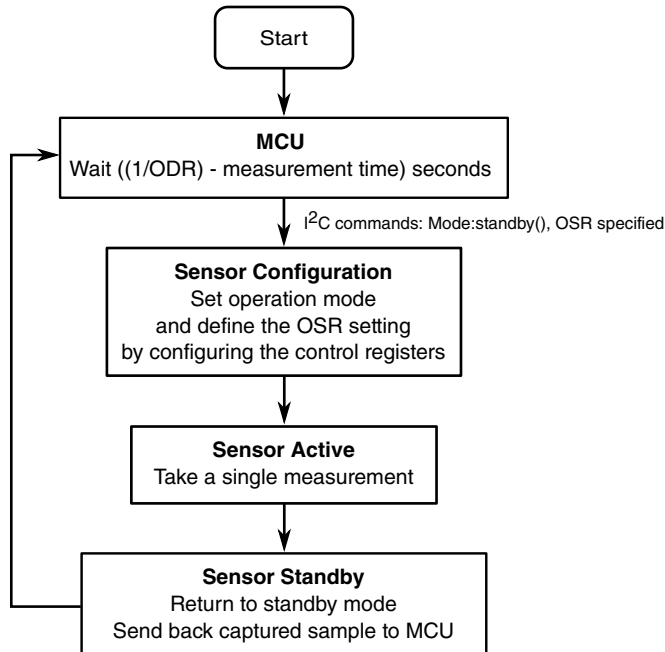


Figure 1. One-shot method operational flow

3.2 One-Shot Method Application Circuit—MAG3110

Figure 2 shows the electrical connections for one-shot method using the Freescale MAG3110 magnetometer. Current consumption is indirectly measured from the voltage across R1.

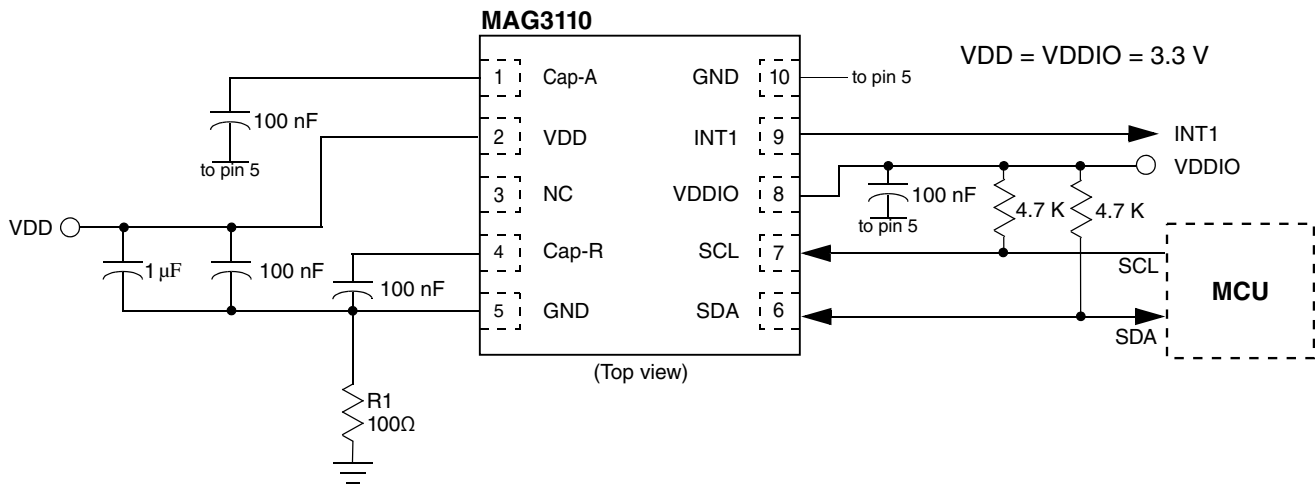


Figure 2. One-shot method application circuit—MAG3110

Figure 3 shows current consumption pattern of the MAG3110 as it transitions from the standby phase, through a 16x OSR measurement phase and then back to the standby phase.

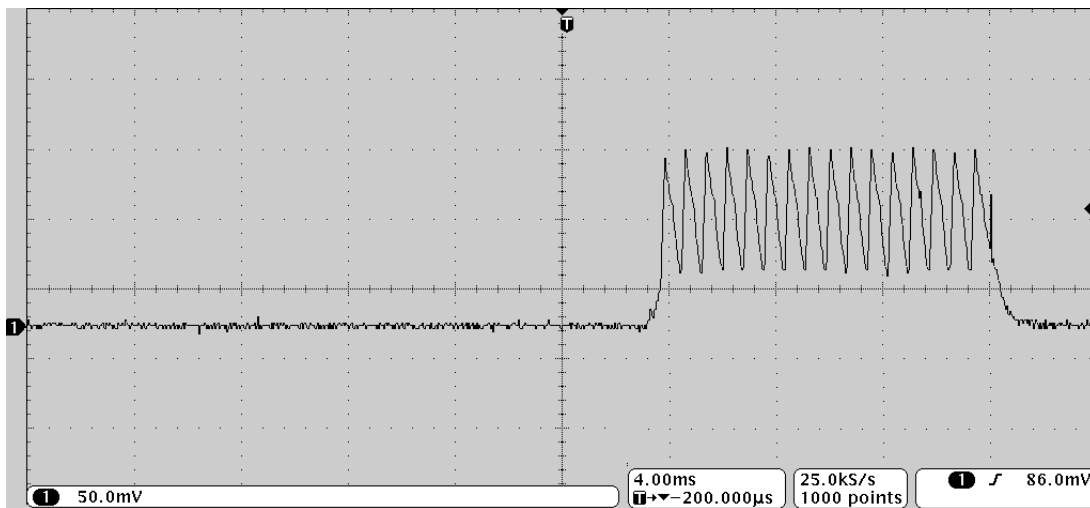


Figure 3. Current (as voltage variations across R1) vs. time for one-shot method—MAG3110

3.3 One-Shot Method Application Circuit—FXOS8700

Figure 4 shows the electrical connections for one-shot method using Freescale FXOS8700 magnetometer. Current consumption is indirectly measured from the voltage across R1.

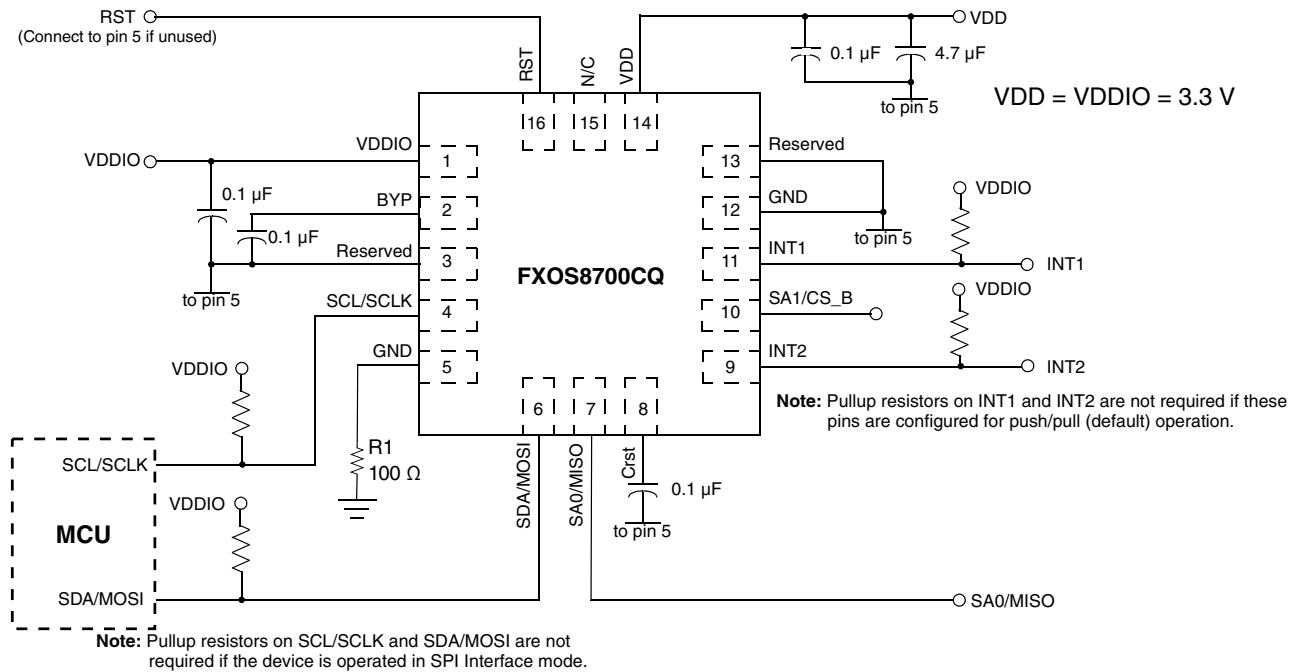


Figure 4. One-Shot method application circuit—FXOS8700

4 Power Cycling Measurement Method

4.1 General Description of Power Cycling Measurement Method

The power cycling method is an extension of the one-shot method. The sensor is immediately powered off after the measurement and powered on just before the next measurement. This mitigates the standby mode current consumption during the Sensor OFF phase.

The operational flow for power cycling the sensor and taking measurements is shown in Figure 5.

The sensor is completely powered off during the Sensor OFF phase of the measurement cycle, resulting in zero standby current during this phase.

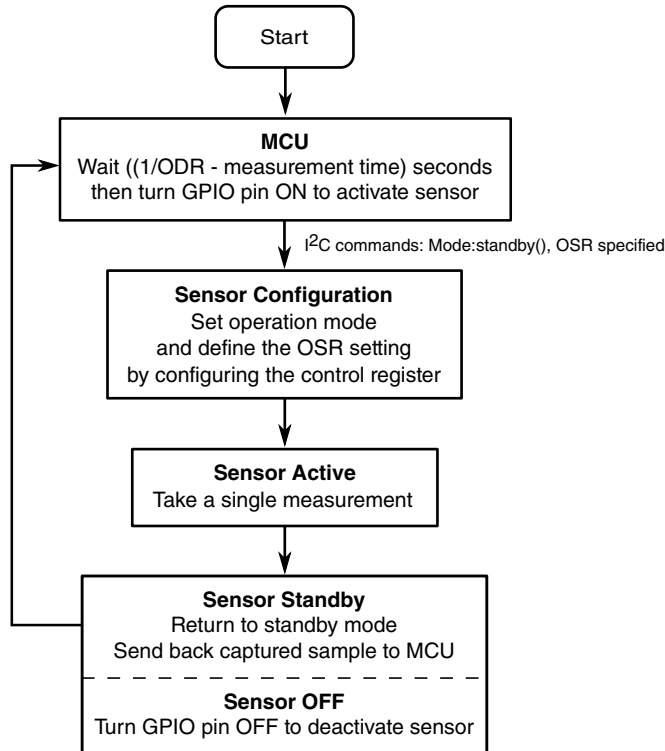


Figure 5. Power cycling method operational flow

4.2 Power Cycling Method Application Circuit—MAG3110

Figure 6 shows the electrical connections for power cycle method using the Freescale MAG3110 magnetometer. Current consumption is indirectly measured from the voltage across R1.

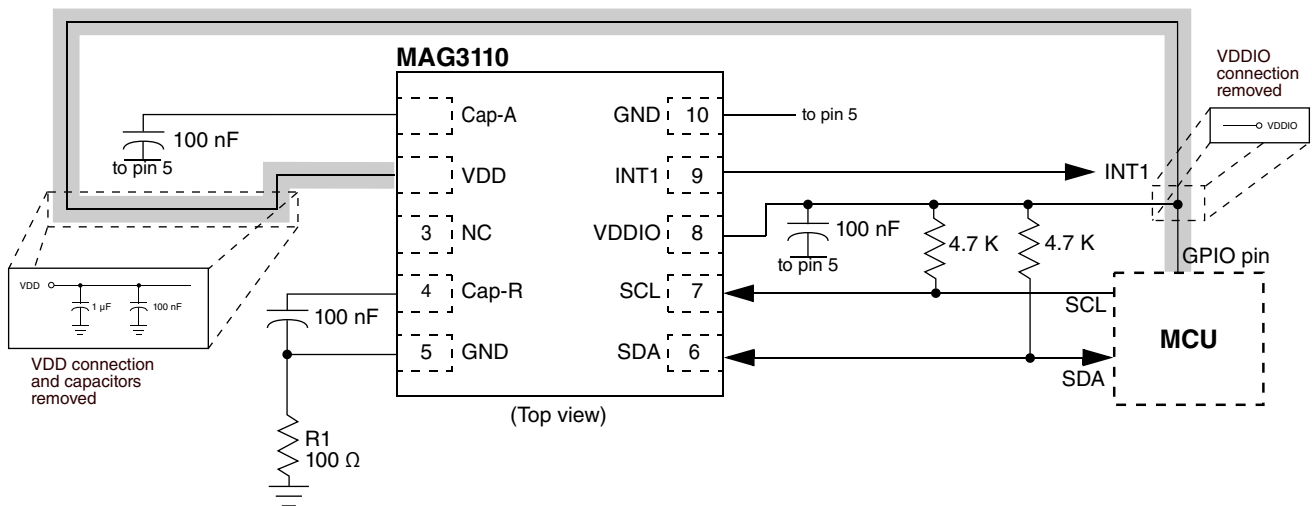


Figure 6. Power cycling method application circuit—MAG3110

Power Cycling Measurement Method

The capacitors of the MAG3110 supply rail (see [Figure 2](#)) in the sensor undergoes a periodic charge and discharge cycle when the sensor is powered on or off. In the power cycling method, to reduce the charge/discharge time period and the associated current consumption, the bypass capacitors in the V_{DD} line are removed and both V_{DD} and V_{DDIO} are tied together such that they share a common $0.1\ \mu\text{F}$ capacitor (see [Figure 6](#)). The $0.1\ \mu\text{F}$ capacitor minimizes the average current while still maintaining an acceptable level of power supply high-frequency filtering. [Figure 8](#) shows that noise levels are well maintained, based on distributions of 10,000 data samples obtained under standard and power cycling measurement methods.

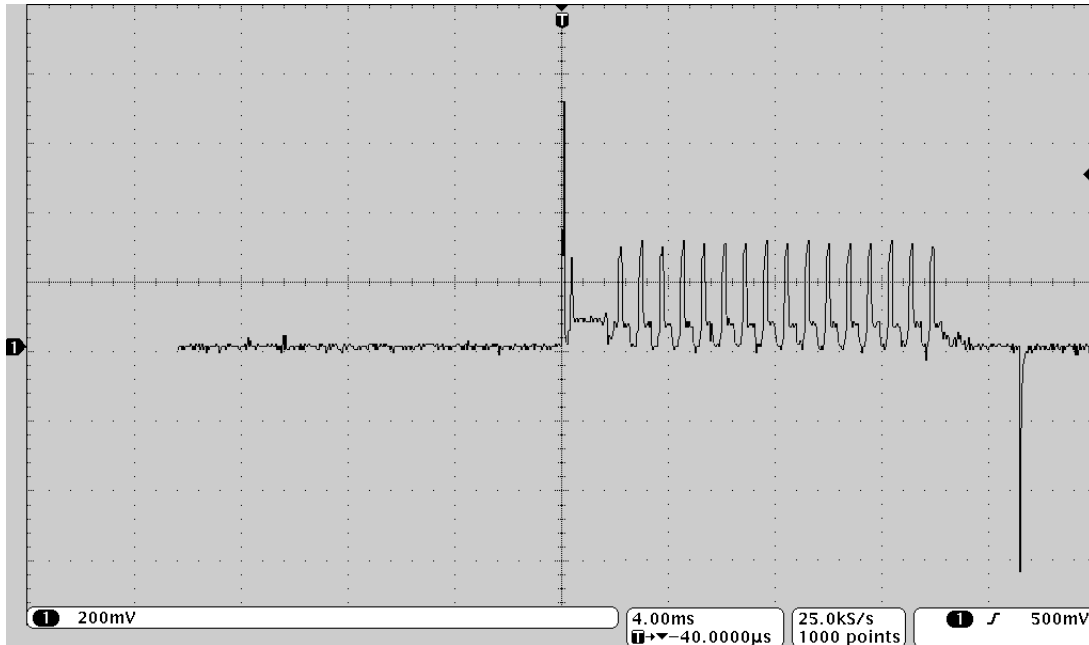


Figure 7. Current vs. time for power cycling method—MAG3110

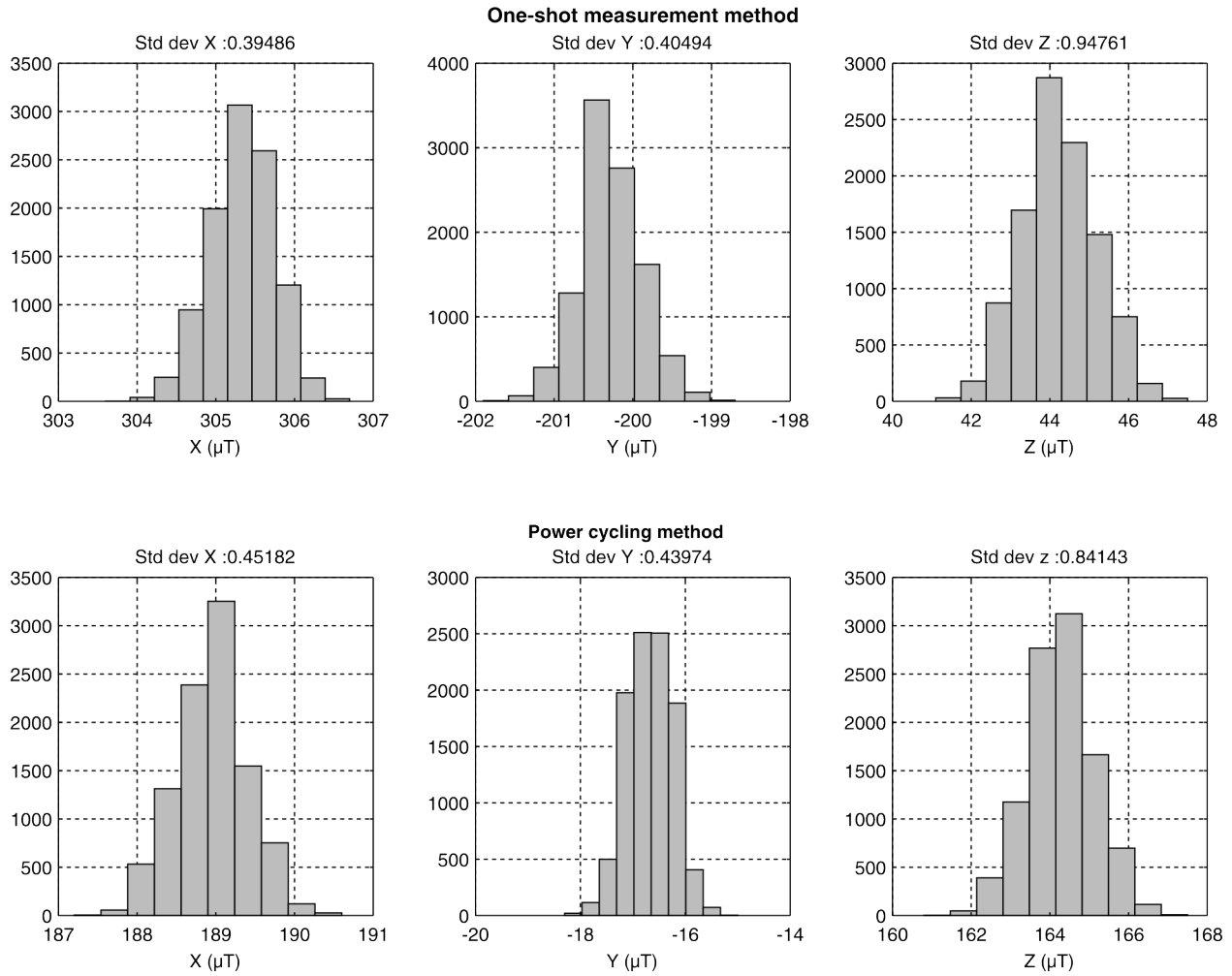


Figure 8. Data distribution for MAG3110

4.3 Power Cycling Method Application Circuit—FXOS8700

Figure 9 shows the electrical connections for power cycle method using the Freescale FXOS8700 magnetometer. Current consumption is indirectly measured from the voltage across R1.

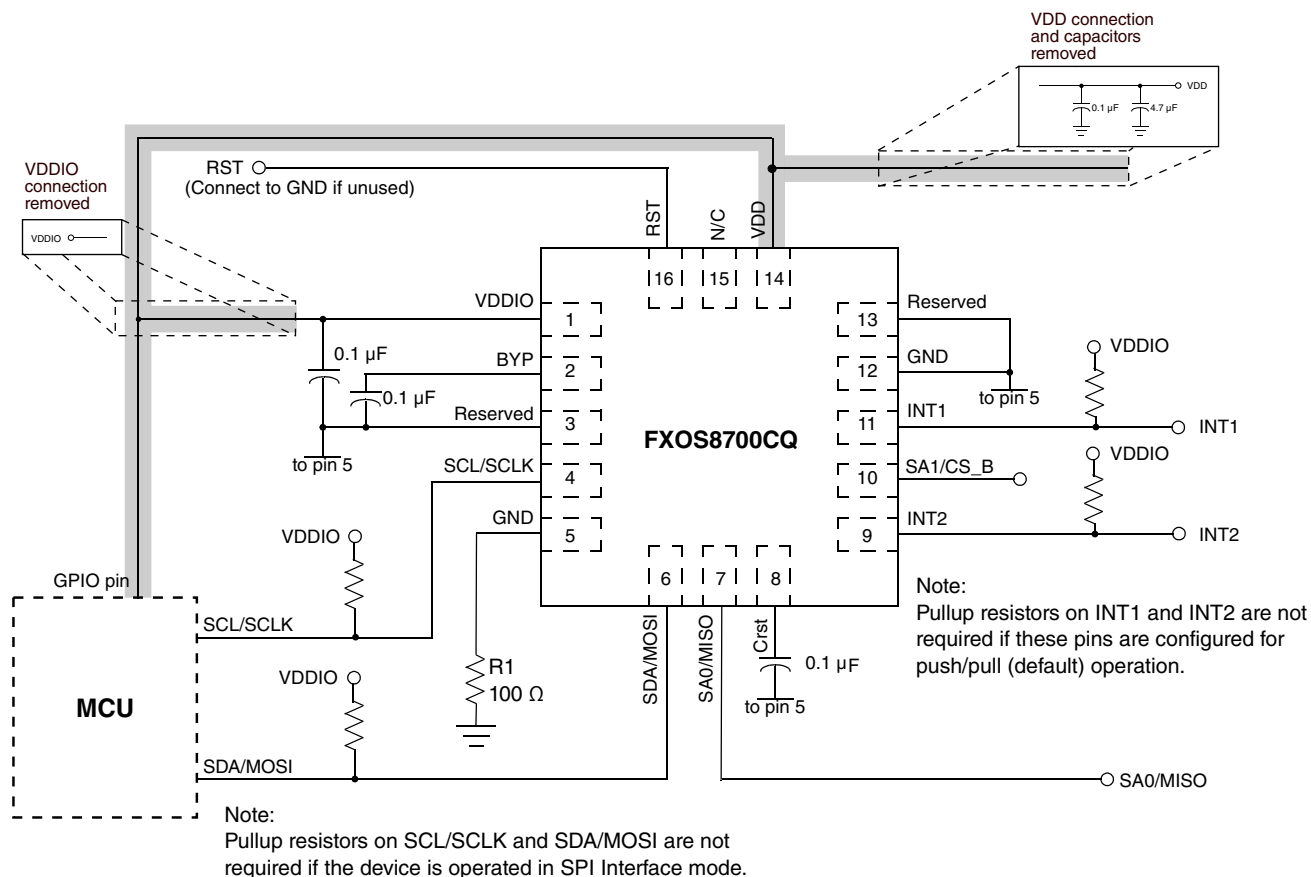


Figure 9. Power cycling method application circuit—FXOS8700

In one-shot measurement method, the capacitors of the FXOS8700 supply rail (see Figure 9) in the sensor undergoes a periodic charge and discharge cycle when the sensor is powered on or off. In the power cycling method, to reduce the charge/discharge time period and the associated current consumption, the bypass capacitors in the V_{DD} line are removed and both V_{DD} and V_{DDIO} are tied together such that they share a common 0.1 µF capacitor (see Figure 9). The 0.1 µF capacitor minimizes the average current while still maintaining an acceptable level of power supply high-frequency filtering.

5 Register Level Configuration

Except for the circuit setup, the configuration of the registers is identical for both modes.

5.1 MAG3110 Register Configuration

To configure the MAG3110 to operate in one-shot measurement mode, configure the control register **CTRL_REG1**.

Sample setup: One-shot measurement with OSR = 16

1. Initiate a triggered measurement with OSR = 16 by writing 0xC2 to **CTRL_REG1**. Bit AC = 0 enables the standby mode of operation.
2. The sensor acquires the measurement and returns back to standby mode.

Reinitiate the measurement by going repeating step 1 after a delay of 1/ODR ms.

5.2 FXOS8700 Registers

To configure the FXOS8700 to operate in one-shot measurement mode, configure the control register **CTRL_REG1** (0x2A) and the magnetometer control register **M_CTRL_REG1** (0x5B) to set the OSR value. Note: the accelerometer in FXOS8700 is not used so its corresponding control register is not configured and the sensor is disabled.

Sample setup: One-shot measurement with OSR value of 2

1. Configure the sensor by writing 0x00 to **CTRL_REG1** (0x2A). Bit AC = 0 enables the standby mode of operation.
2. Initiate the triggered measurement with OSR id set to 0 in **M_CTRL_REG1** (set ODR in **CTRL_REG1** such that OSR can take a value = 2. The set of possible OSR values in **M_CTRL_REG1** depends on the ODR setting in **CTRL_REG1**). The value of ODR is of no importance as the device is not in active mode.

Write 0x61 to the **M_CTRL_REG1**. The `m_ost` bit is set for one-shot measurement. The sensor acquires the measurement and returns back to standby mode.

Reinitiate the measurement by going back to step 2 after a delay of 1/ODR ms.

6 Comparative Analysis

6.1 ADC Settling Time

The first ODR sample will have settling errors due to delays in the analog front end's anti-aliasing filter. The amount of the settling error is inversely proportional to the OSR setting. However the settling error occurs only in the first sample, as long as the sensor is not power cycled. Therefore, in the power cycling mode, the first sample in each measurement cycle should be discarded. This doubles the measurement time of the power cycling method, as compared to one-shot method.

One-shot method

Sensor

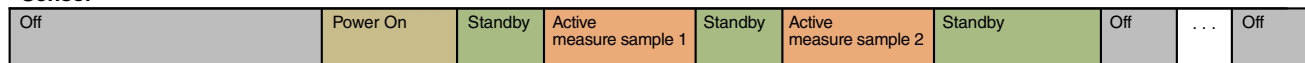


MCU



Power cycling method

Sensor



MCU



Figure 10. CPU Timing diagram

6.2 Current Consumption Characteristics—Comparative Analysis

Figure 11, Figure 12 and Table 1 show the comparative analysis of the one-shot method and the power cycling method for both sensors.

- For FXOS8700, at ODRs less than 0.5 Hz, average I_{DD} current is less when using the power cycling method, compared to using the one-shot method.
- For MAG3110, at ODRs less than 0.15 Hz, average I_{DD} current is less when using the power cycling method, compared to using the one-shot method.

The crossover point for the FXOS8700 is at higher ODR than the MAG3110 due to its oversampling ratio of 2, compared the the MAG3110 oversampling ratio of 16.

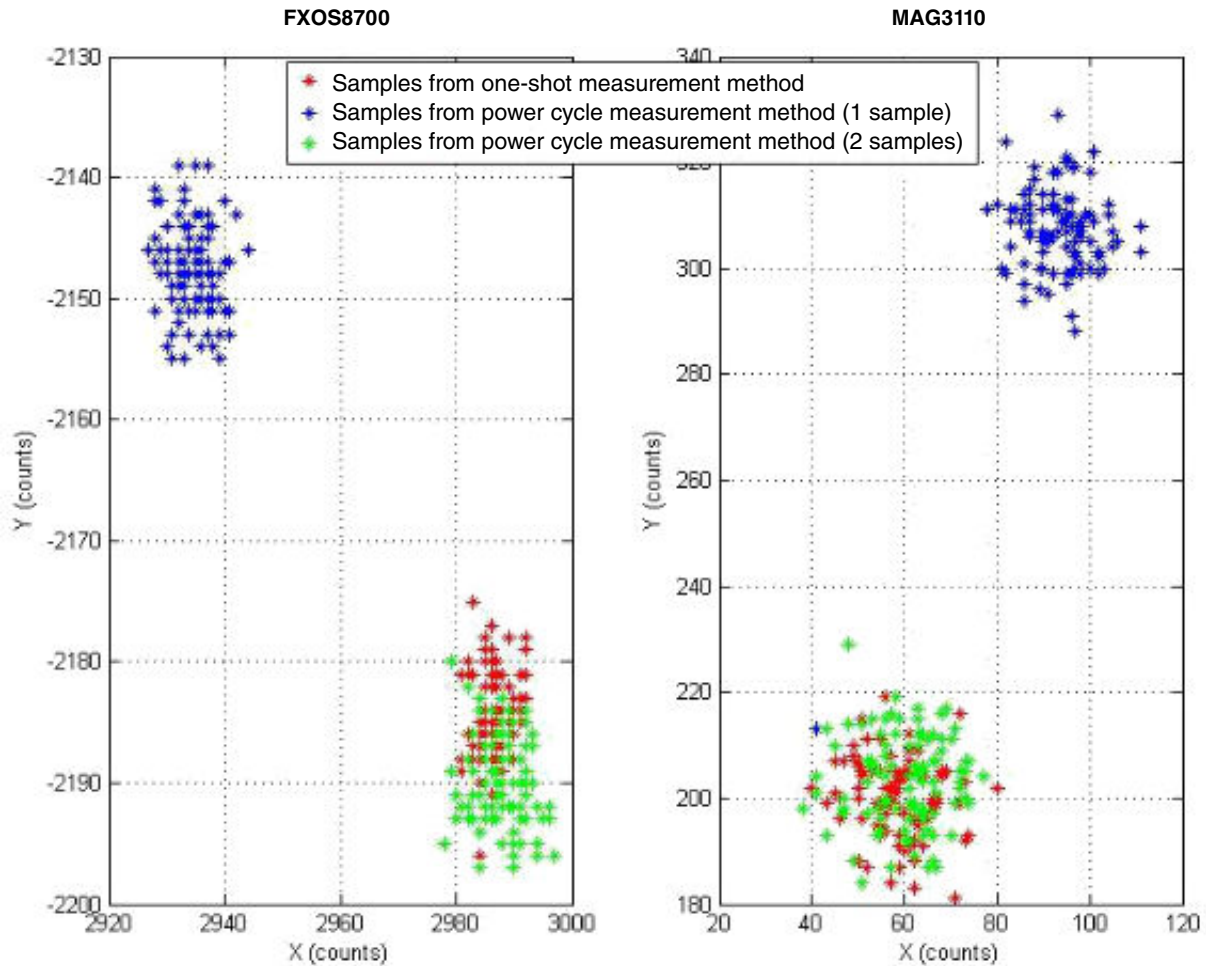
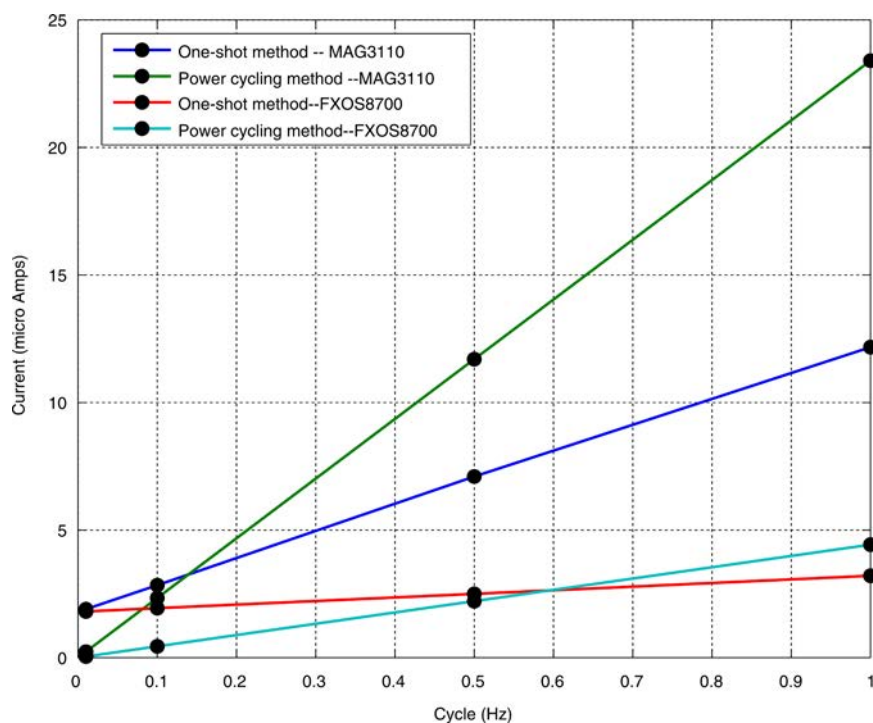


Figure 11. ADC settling time

Table 1. Average current consumption characteristics

ODR (Hz)	Average current consumption (μA)			
	MAG3110		FXOS8700	
	One-shot measurement mode	Power cycling measurement mode	One-shot measurement mode	Power cycling measurement mode
1	12.17	23.4	3.21	4.43
0.5	7.1	11.7	2.5	2.215
0.1	2.84	2.34	1.94	0.443
0.01	1.90	0.234	1.81	0.0443

**Figure 12. Current consumption per cycle (one-shot method vs. power cycling method)**

6.3 Operating Temperature and Battery Drain Studies

The operating range of MAG3110/FXOS8700 is -40 to $+85$ °C. The standby current varies in this range as shown in [Figure 13](#). At 60 °C, the standby current drain is approximately 3 μA . The IDD/ measurement cycle increases from the nominal operating current drain of 2 μA @ 20 °C as shown in [Figure 14](#). For high temperature use cases, the power cycling method is preferred over the one-shot method. The power cycling method is the recommended low power solution when the sensor is operated in a wide temperature range.

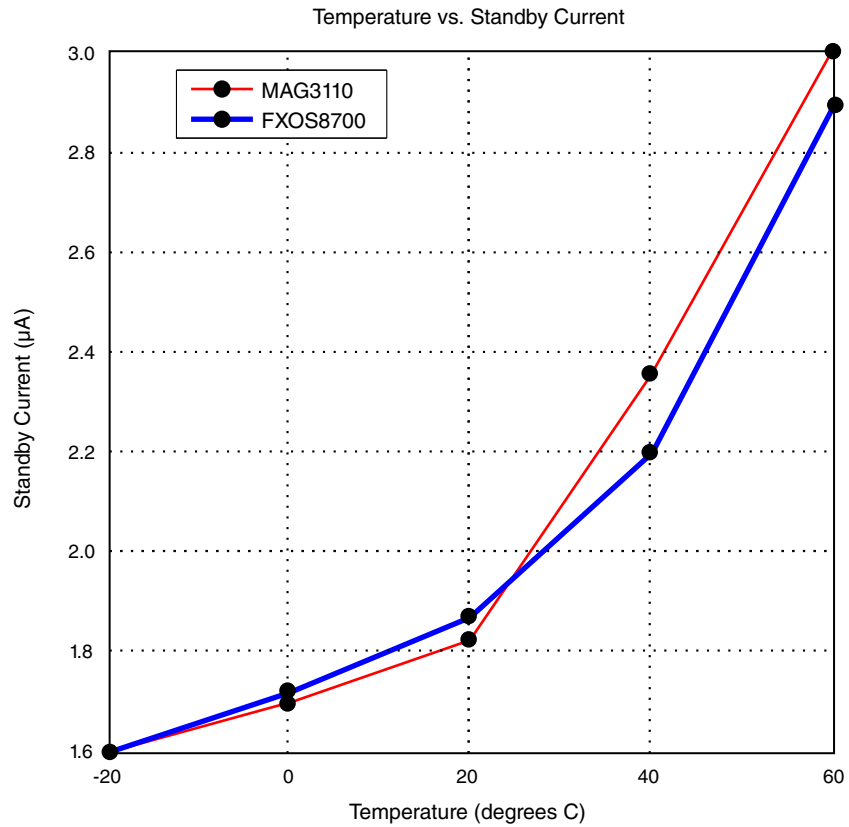


Figure 13. Standby current variation vs. temperature

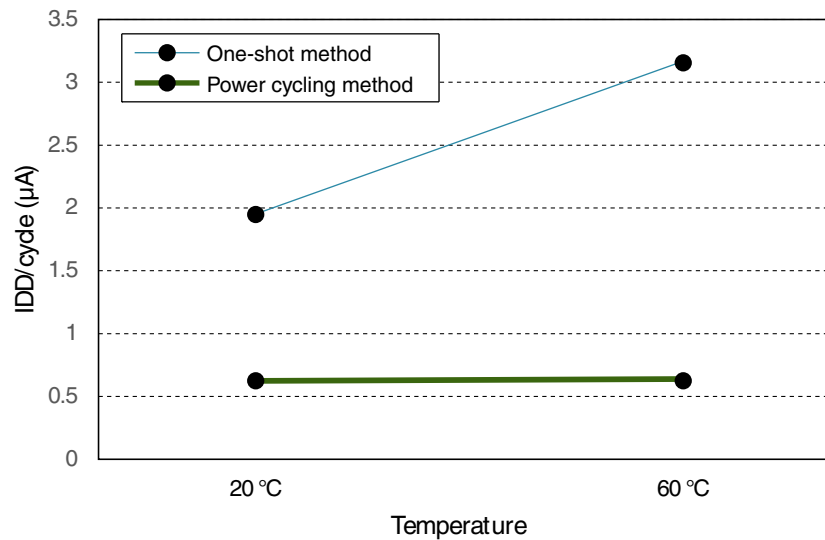


Figure 14. Current consumption per cycle vs. temperature for both modes

Figure 15 shows the system (MCU + Sensor) level power consumption for both implementation methods. Note that the MCU must communicate with the sensor on an interrupt (data ready) basis to minimize MCU power consumption. The host processor can operate in low power modes during the sensor measurement time and in RUN mode while servicing the interrupt and initializing the sensor as shown in figure. The data values shown in the figure correspond to Freescale's HCS08 low power MCU solution.

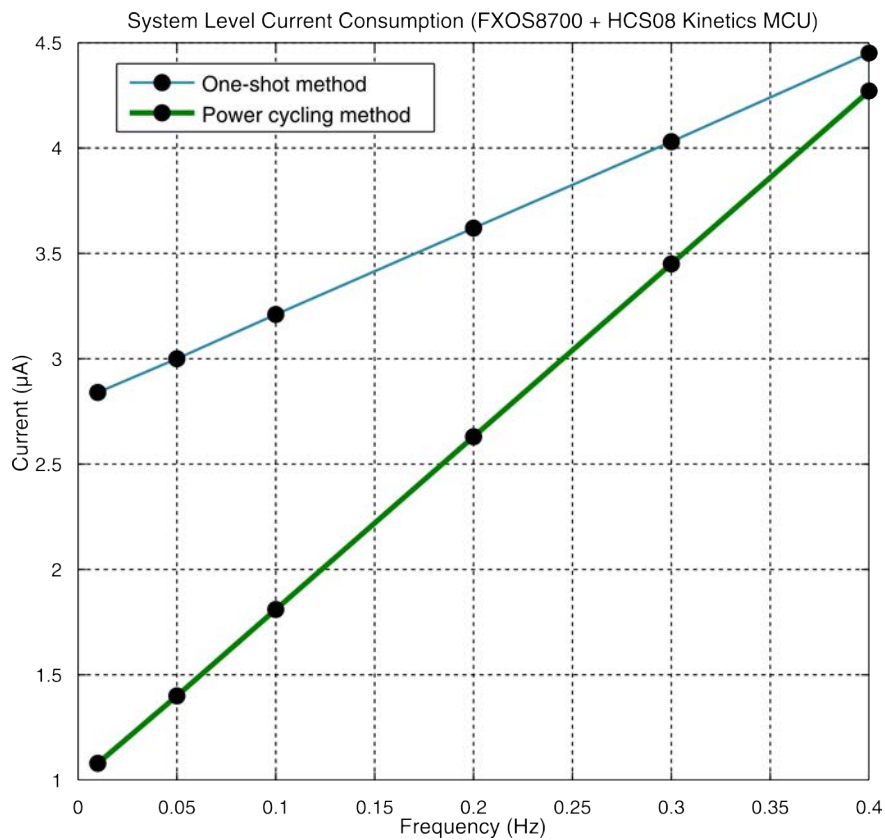


Figure 15. System Level Current Consumption

7 References

Freescale FXOS8700CQ 6-Axis Sensor with Integrated Linear Accelerometer and Magnetometer (data sheet), Document Number FXOS8700.

Freescale MAG3110 Three-Axis, Digital Magnetometer (data sheet), Document Number MAG3110.

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