XEN1220
Differential Ratiometric Magnetic Sensor

Features

- **Differential ratiometric magnetic measurement**
- **One chip solution**
- **15nT resolution**
- **Unmatched low offset (Sub-µT) and gain precision**
- **Wide magnetic field range (±63mT)**
- **No magnetic hysteresis**
- **Measurement rate up to 5kSPS**
- **Low voltage operation (2.5V to 3.3V)**
- **Single supply**
- **Serial SPI communication**
- **-40°C to 125°C Temperature Range**
- **Available in reel**

General Description

XEN1220 is a differential magnetic field sensor based on the Hall effect. It uses Sensixs's Q-Hall technology, which with a resolution of 15nT and a magnetic field range of 63mT combines the best of Hall and AMR technology in one.
In position and speed applications where conventional Hall and AMR technology suffer from a large natural offset (drift), its unmatched low offset and offset stability simplifies the design.

The XEN1220 contains two identical well matched hall plates, which can be readout in a differential way or both be added. So a ratio-metric differential reading can be made. The XEN1220 can be used for a wide range of magnetic sensing applications.
Its magnetic readout can be programmed between reading out the left hall plate, the right hall plate, the addition of both or the difference of both.

A maximum read-out frequency of 5kSPS can be obtained. The control is fully digital and readout and programming is performed via the SPI bus.

For battery applications, power can be saved by taking single shot measurements. In power-off mode the current draw is limited to below 100nA.

The XEN1220 is available in non-magnetic MSOP packages.

Applications

- Linear Magnetic Field Sensor
- Linear Position and Speed Measurement
- Rotary Position and Speed Measurement
- Current Sensing

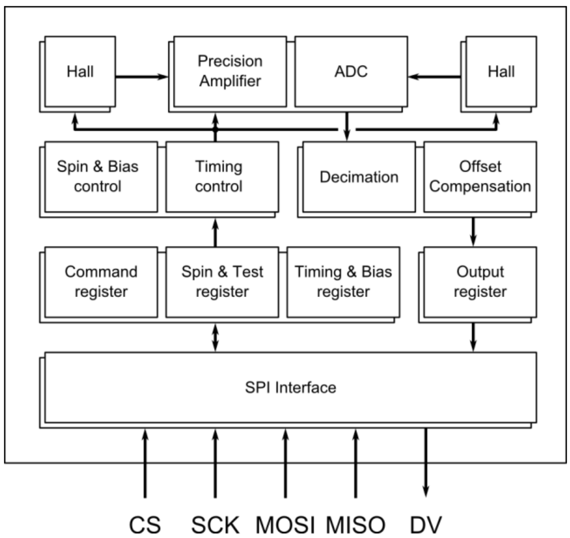

Figure 1: Functional block diagram.

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Specifications

Table 1: Specifications for the XEN1220.

Specification	Conditions	Min	Typ.	Max	Unit
Power supply					
VDD		2.5	3.3	3.6	V
IDD	Sleep mode		50		nA
	Idle mode		10		µA
	Power-up mode (Always On)		4.7		mA
Magnetic Specifications					
Field Range			±63		mT
Gain mismatch	Between XEN1220 samples (sigma)		1		%
Gain TC	Between XEN1220 samples (mean TC)		600		ppm/K
Gain TC mismatch[1]	Between XEN1220 samples (sigma TC)		60		ppm/K
Gain mismatch	Between internal Hall plates (sigma)		0.5		%
Gain mismatch TC	Between internal Hall plates (mean TC)		15		ppm/K
Gain mismatch TC mismatch	Between internal Hall plates (sigma TC)		15		ppm/K
Offset	Without calibration		1		µT
Offset TC			10		nT/K
Resolution (24 bits[2])			7.5		nT/LSB
Noise			55		nT/√Hz
Hysteresis				10	nT
Maximum exposed field	No effect				
System speed					
CLK[3]		0.8	1	5	MHz
Sample speed	5Mhz CLK			5	kHz
Turn on time	5kHz programmed measurement time, device needs no additional turn on time.	200			µs
SPI Bus					
SPI Speed			400		kHz
Temperature					
Temperature Range		-40		+125	°C

Magnetic Flux Density: 100 micro Tesla (µT) = 1 gauss (G) =1Oe (in air)
Magnetic Field: 1 oersted (Oe) = 79.58 amperes/meter (A/m)
100 000 gamma = 1 Oe = 79.58 A/m

[1] Single batch data.
[2] The LSB is used for encoding the data valid flag, therefore the maximum obtainable resolution is 15nT, this is however well below the practical noise floor, so if the data valid flag is not used, no bitwise masking is required.
[3] XEN1220 needs a stable clock frequency.

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Introduction

The XEN1220 is a CMOS linear magnetic field sensor with a very low offset, and two hall plates. It uses Sensixs patented high performance spinning-current Hall-plate technology, a precision amplifier and a sigma delta AD converter, and offers full digital control and communication through a SPI serial bus.

The XEN1220 contains two identical well matched hall plates, which can be readout in a differential way or both be added. So a ratio-metric differential reading can be made. The XEN1220 can be used for a wide range of magnetic sensing applications.
Its magnetic readout can be programmed between reading out the left hall plate, the right hall plate, the addition of both or the difference of both.

Speed and internal measurement time can be changed at will. The clock frequency in combination with the setting in the speed register determine the measurement time of the device from 0.2ms to 66ms. The device can be read out using the data valid signal as an interrupt for the Host CPU or at any desired readout speed. A data-valid flag is present in the data itself.

The device addresses a large magnetic range without the need of gain settings. A 24-bit digital output is provided.

There is no power-up reset so the device has to be initially programmed by the host CPU each time the supply is switched on. The device can be put in sleep mode, idle mode, in continuous measurement mode or in single shot mode. The main use of these modes is the preservation of power.

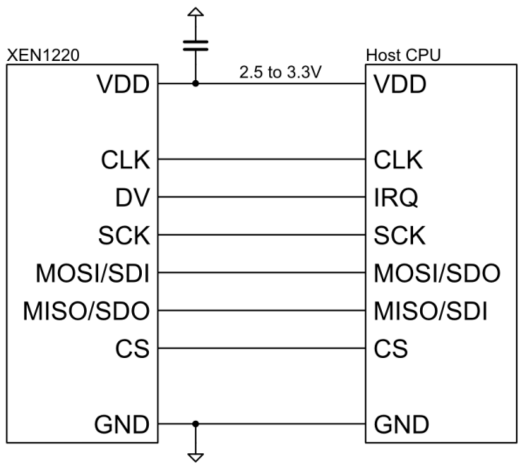

Figure 2: Typical connection scheme of a XEN1220 to a Host CPU. A 100nF decoupling capacitor can be used when the supplies are not clean.

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Digital Communication - SPI interface

Communication with the XEN1220 occurs via the serial SPI interface. The SPI interface is externally controlled by four signals : chip select (CS), serial clock (SCK), serial data in (SDI), and serial data out (SDO). SPI mode is 1, which means that SCK has a zero base value (CPOL=0) and data is read on SCK's falling edge, while data is changed on the rising edge (CPHA=1). Typically the speed of SCK is 100kHz. Read-out speeds up to 1Mhz are allowed as long as the T_{buf} is satisfied. T_{buf} is typically two times the CLK period.

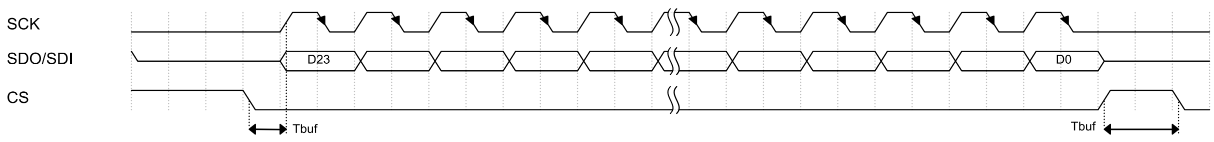

Figure 3: Timing of the SPI bus interface with chip select, clock, and data signals.

The SPI interface has one serial shift register and two buffers: a receive-buffer in which the data is loaded from the shift register at the end of CS, and a transmit-buffer from which the data is loaded into the shift register at the beginning of CS. Writing the SPI register will shift in serial data from SDI and shift out serial data from SDO pin. Reading and writing is therefore always performed simultaneously.
Transmission always goes in a multiple of 3 bytes with the MSB (bit D23) send first. The SPI interface is still operational when the device is in power-off mode.

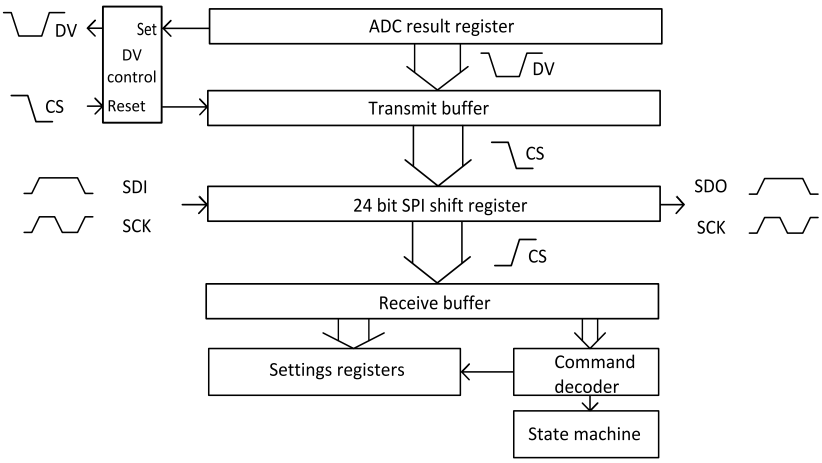

Figure 4: Functional block diagram SPI register.

Data Output Format

The XEN1220 provides a 3-byte result in two's complement code. Table 2 shows the digital encoding of the magnetic reading. Data is double buffered and can be read out any time. When new data becomes available through the internal ADC, the XEN1220 pulls down the data valid pin for one clock period and refreshes the 3 byte transmit buffer. The LSB (bit D0) of the buffer is also used as a data valid flag.
When the transmit buffer is loaded into the SPI register at the start of a SPI transmission, the data valid flag is reset to 0. When new ADC data is loaded into the transmit buffer, the DV flag is set to 1. This helps to see if the last read data is new or if it has been read before. If data is not read before a new sample of the ADC is available it is lost. Since the system noise is usually higher than the LSB, it is not strictly necessary to bit-wise mask the data-valid flag, when calculating the magnetic field strength.

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Table 2: Decoding the two's complement code and data-valid flag.

LSB's	HEX code	Field strength	Remarks
+ 2^{23} -1	0x7FFFFF	+63 mT	
+ 255	0x0000FF	+1.9 µT	
+3	0x000011	+21.5nT	Data valid
+2	0x000010	+15nT	Data non valid.
+1	0x000001	+7.5nT	Data valid
0	0x000000	0	Data non valid.
-1	0xFFFFFF	-7.5nT	Data valid
-255	0xFFFF01	-1.9 µT	
- 2^{23}	0x800000	-63 mT	

Data Read Out

When the XEN1220 is read out, care has to be taken that the SDI pin is high. The SDO pin of the host CPU connected to this SDI should be high or high impedance. In the latter case the internal pull-up of the XEN1220 SDI pin ensures a high state. This is necessary to avoid that the device's operation is changed by unintentionally programming it.

Commands

The XEN1220 can be controlled and the settings programmed by sending commands over the SPI bus. Commands are coded in a 3-byte format. The first byte (D23-D16) is the program byte, which defines the desired action. The two remaining bytes (D15-D8 and D7-D0) are the setting bytes, which control the speed and biasing of the device.

Operation Commands

The XEN1220 can be controlled with 4 operation commands: power-on, power-off, system-reset, and single-shot. With these commands only the program byte is used and the setting bytes are ignored. The primary purpose of the modes is system synchronization and power management.

Table 3: Operation commands used with the XEN1220.

Operation Command	Program Byte
System-Reset	0x10
Power-On	0x20
Power-Off	0x40
Single-Shot	0x60

Reset

The reset command is used during power-on to reset the state machine of the XEN1220 to its initial state, devices can be synchronized as a group or individual.

Power-off

The power-off command switches off the power to all circuits except for the SPI interface. Communication and programming is still possible during power-off. Power consumption in this mode is several micro-amps.

For full system power saving mode CLK has to be pulled low as well. This also stops the SPI communication. Power consumption during power-off will be less than 100nA.

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Power-on
The power-on command applies power to all circuits. When sending power-on, the system also resets with a system reset command. In this mode measurements are taken continuously and can be read from the SPI bus.

Single-shot
The single-shot command calls the power-on command, performs a single measurement, and calls the power-off command. It is very important NOT to send a new single-shot command before the previous command sequence has finished. This is indicated by the data-valid pulse on the DV pin. If the single-shot command is send before the previous command sequence has finished then the XEN1220 is reset, so the previous single shot sequence will not finish and no new data is provided. The time needed for a single-shot sequence depends on the timing settings of the XEN1220. The single-shot command only works when the device is powered off. In this mode, power can be saved by using the device only when data is required.

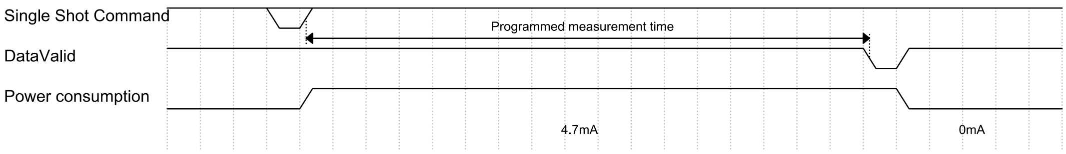

Figure 5: The measurement time after a single shot command depends on the timing settings. Only during measurement power is consumed.

Settings Commands

The XEN1220 contains three internal registers to store settings for the analog front end of the ASIC and some digital settings such as the sensors speed. These are called the timing register, the test register and the magnetic register. All registers are double buffered and settings are first stored before they are used to control the chip. In this way the settings of for example input multiplexers can be synchronized with the internal integrating ADC. It is possible to immediately write and use the settings, it is possible to write and use the settings only on the next datavalid and it is possible to write the settings and use the settings of all of the newly written registers on one and the same next datavalid

Table 4: Setting commands used with the XEN1220.

Settings Command	Program Byte	Setting Bytes	Remarks
Timing register	0x01	Table 5	Wait with use till DataValid sync.
Timing register	0x05	Table 5	Direct Use
Timing register	0x09	Table 5	Use on next DataValid.
Test register	0x02	Table 6	Wait with use till DataValid sync
Test register	0x06	Table 6	Direct use.
Test register	0x0A	Table 6	Use on next DataValid
Magnetic register	0x03	Table 7	Wait with use till DataValid sync
Magnetic register	0x07	Table 7	Direct Use.
Magnetic register	0x0B	Table 7	Use on next DataValid
Sync All on next DV	0x0C		Use all stored on next DataValid

Settings Commands

Timing settings

The timing settings control the speed of measurement. There are 7 settings, with each step doubling the number of clock cycles used in the internal ADC. The total conversion time is still dependent on the frequency of CLK. In Table 5, two situations have been calculated: one at 1MHz clock speed, and one at 5MHz clock speed.

Table 5: Read out frequency and measurement time for the speed settings and 1MHz or 5MHz clock.

		1MHz			5MHz		
Timing Settings	Clock Cycles	Time [ms]	Max SPS [Hz]	Noise (σ) [μT]	Time [ms]	Max SPS [Hz]	Noise (σ) [μT]
0x0113	512	0.5	1953	3.2	0.20	9766	9
0x1113	1024	1.0	976	2.3	0.20	4882	5.1
0x2113	2048	2.1	488	1.6	0.41	2441	3.6
0x3113	4096	4.1	244	1.2	0.82	1220	2.6
0x4113	8192	8.2	122	0.81	1.64	610	1.8
0x5113	16384	16.4	61	0.57	3.28	305	1.3
0x6113	32768	32.8	30	0.41	6.55	152	0.91
0x7113	65536	65.5	15	0.29	13.1	76	0.64

Test settings

The settings for test are not used in normal operation, however, the test register has to be programmed by standard settings. Its value is shown in Table 6 and should not be changed.

Table 6: Test settings.

Test Settings
0x3A00

Magnetic settings

Only the last byte is used for programming the magnetic settings. The difference between current switched and current always on is that the currents switched will consume a bit more power and current always on will have a more stable signal.

Table 7: Coding of the read-out of the two hall plates.

Setting	Magnetic Settings Byte
Automatic additive readout	0x0000
Automatic differential readout	0x0001
Left plate readout	0x0017
Right plate readout	0x001E

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Combined Commands

Operation commands and setting commands can be combined, by adding the command codes. This is most useful for the single shot command, where a sample time can be programmed for each individual single shot.

Table 8: Combined commands.

Command	Program Byte	Setting Bytes
Single-Shot and Timing	0x61	0x1113

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Typical initialization and operation

Power supply on initialization
The XEN1220 does not reset when power is applied, and the device has to be fully programmed before use. Good programming practice is to first send a power-off command and then program both timing and test registers with the desired settings.

Table 9: Device initialization sequence.

Command	Program Byte	Setting Bytes
Power-Off	0x40	0x0000
Timing	0x01	0x1113
Test	0x02	0x3A00
Magnetic reading	0x03	0x0000

Full Power Mode
A full-power operation can be entered by sending the power-on command. Directly after sending the power-on command, all devices that are connected to the bus are synchronized and will start measuring continuously at the programmed speed.
The XEN1220 data can now be read by either using the DV pin as an interrupt, or by just clocking out the SPI data. Duplicate data can be filtered by looking at the data valid flag in the LSB of the data word.

Table 10: Device put into continuous measurement mode.

Command	Program Byte	Setting Bytes
Power-On	0x20	0x0000

Reprogramming during operation
Because settings are implemented immediately, reprogramming during operation should be combined with a system synchronization command. This will prevent a change of settings while a measurement takes place, which can lead to incorrect magnetic readings. Synchronization and reprogramming can be combined in a single command.

Table 11: Reprogramming the device during measurement.

Command	Program Byte	Setting Bytes
Power-On and Timing	0x21	0x1113
System-Reset and Timing	0x11	0x1113

Single-Shot Mode
A single-shot operation with a measurement time of 1ms (with 1MHz clock) is shown in Table 11. The command powers on the device for 1 measurement and powers off immediately after. The device then keeps the data in memory until read by the host CPU.

Table 12: Taking a single shot with a sample time of 1ms.

Command	Program Byte	Setting Bytes
Single-Shot and Timing	0x61	0x1113

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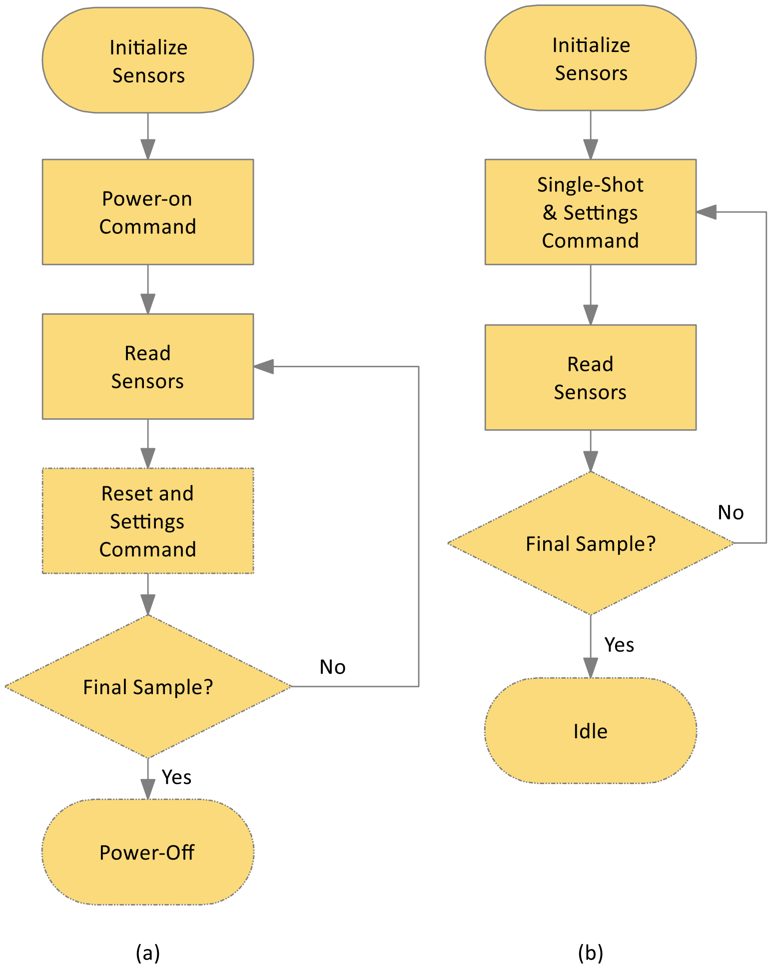

Figure 6: Flow diagram for continuous operation (a) or single shot operation (b).

Connection schemes

By using multiple XEN1220, many magnetic measurement problems can be solved. The devices can be electrically connected in two ways:

Parallel
The devices can be used with SDI and SDO fully parallel and separate CS pins. They are selected individually.

Daisy chain
Several devices can be daisy chained by connecting SDO to the next SDI. As such, they function as one long shift register, so commands and data are sent and received in multiples of 3 bytes. Commands and data of the individual devices in the chain have to be positioned in the correct order.

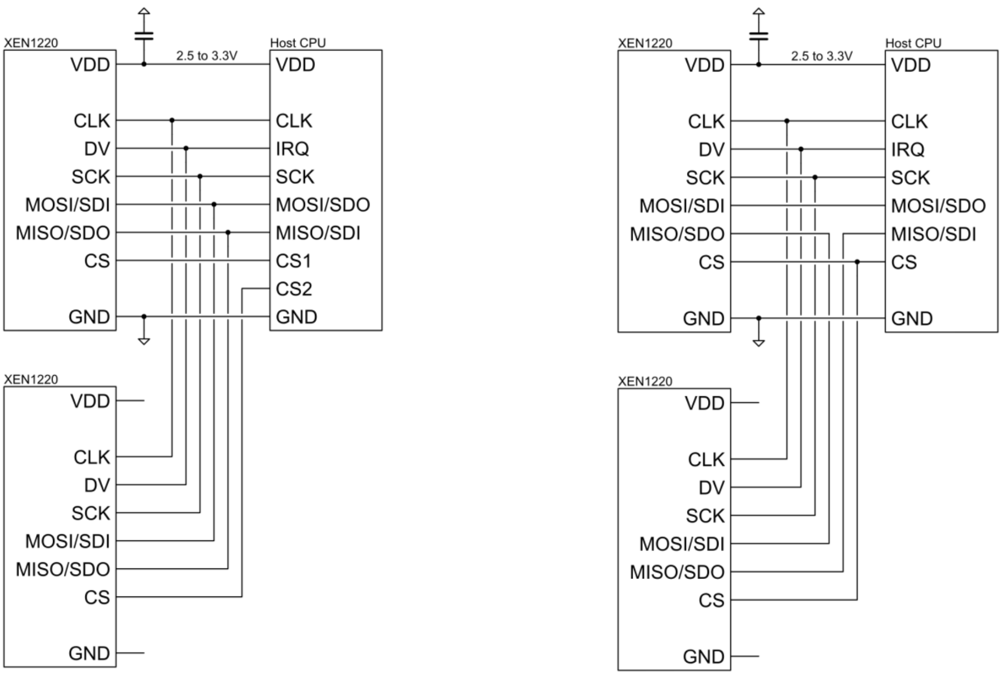

Figure 7: Devices connected in parallel mode use a separate chip select signal (left), and devices connected in daisy chain mode use a single chip select signal and loop the SDI-SDO shift registers (right).

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Ordering information

Table 13: Ordering number.

Ordering number	Product
XEN1220-MSOP8	Single sensor MSOP8

XEN1220 MSOP8

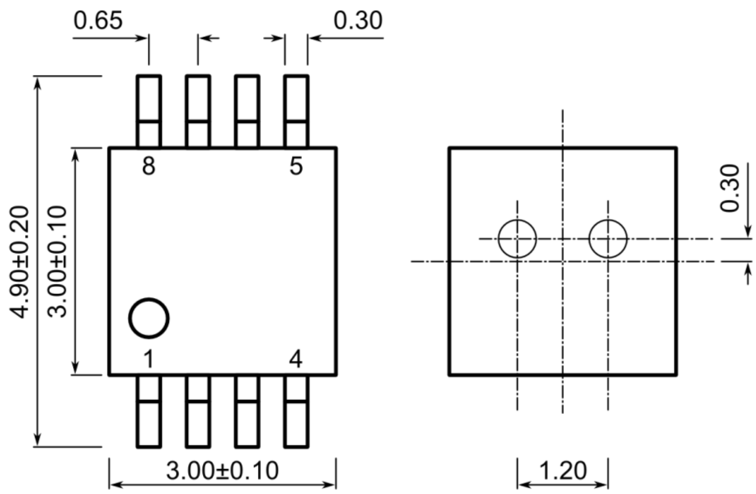

Figure 8 Drawing of the MSOP8 package pin numbering and position of the Hall plates.

Table 14: XEN-1220-MSOP8 pinning

Pin	Name	Type	Functionality
1	CS	Dig. In	Chip Select selects the device when this input is low. A high level deselects the device and forces SDO into tri-state mode.
2	SCK	Dig. In	Serial shift ClocK determines the speed of the SDI/SDO shift register.
3	SDO	Tri-state Out	Serial Data Output pin. Data is shifted out on the positive edge of SCK.
4	GND	Power	Analog and Digital Ground
5	VDD	Power	Analog and Digital Power Supply (2.5V - 3.3V)
6	DV	Dig. Out	The Data Valid pin is pulled down when the internal shift register is refreshed with new data. It can be used as an interrupt signal for the µP.
7	SDI	Dig. In	Serial Data Input pin. Data shifted in is committed on the falling edge of SCK
8	CLK	Dig. In	CLocK is the main clock frequency and determines the speed of the module. Typical clock frequency is 1-5MHz.

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General Information

Product Status

The XEN1220 is in production in MSOP8, and delivered in tubes. ASIC dies, other chip packages, are available on request. The magnetic technology used in the XEN1220 is also available as IP. At higher volumes, application specific products are offered.
Customers are encouraged to check for further product developments. Please contact Sensixs Design b.v. for further details.

Right to make changes

Sensixs Design reserves the right to make changes to improve reliability, function or design of the devices. Sensixs Design assumes no responsibility or liability for the use of this product.

Application Information

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Life critical applications

These products are not qualified for use in life support applications, aeronautical applications or devices or systems where malfunction of these products can reasonably be expected to result in personal injury

Sensixs Design b.v.
Distributieweg 16
2645 EJ Delfgauw
The Netherlands

Phone +31 (0)15-3010018
Web: www.sensixs.nl

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