

LOW NOISE 3D MAGNETIC FIELD TRANSDUCER

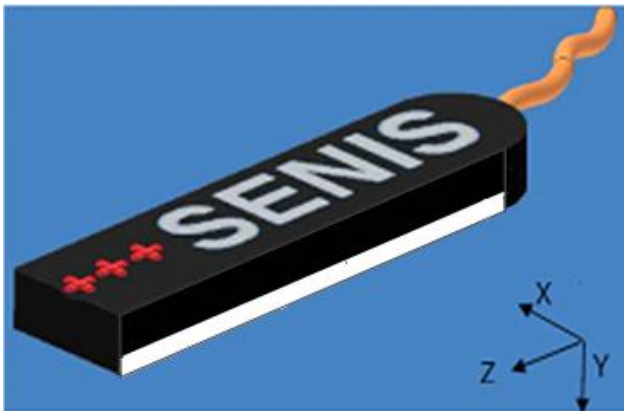


Figure 1. Hall Probe

Key Features

▪ Orthogonality	$< \pm 2^\circ$
▪ Broad-band Noise Y	$B_{RMS} < 1 \mu T$
▪ Offset Drift _{0,1-10Hz} Y	$B_{OF,RMS} < 0.6 \mu T$
▪ Probe's dimensions	2 x 3 x 16.5 mm
▪ Max. meas. range	$\pm 2T$

Description

SENIS transducer 03N08C-G02T0K1M is a high accuracy magnetic flux-density-to-analogue-voltage transducer with a high-level output signal for each of the three components of the measured magnetic flux density.

The transducer consists of two modules (as shown in Fig.1):

1. Hall probe (Module H), and
2. Electronics (Module G).

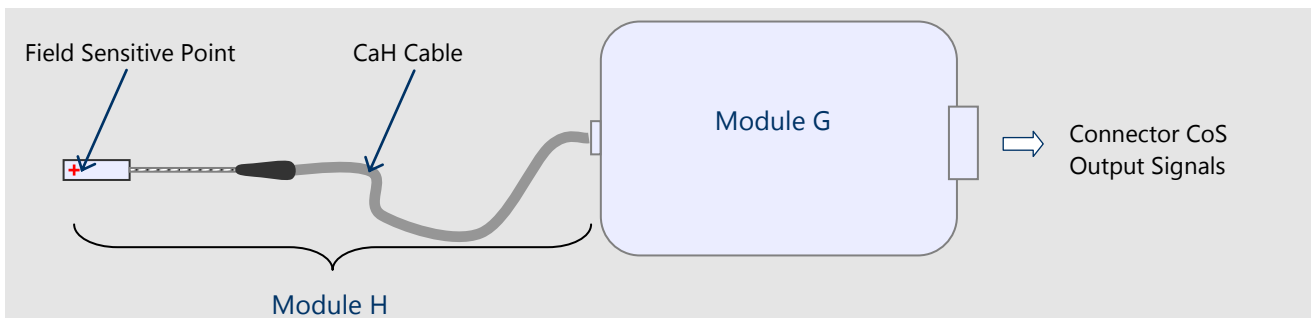


Figure 2. Schema of the SENIS low noise Hall Magnetic Field Transducer:

- Module H, consisting of the Hall Probe and the CaH Cable
 - Module G, Analogue electronics for signal conditioning.
- Note: the Cable CaH is connected with connector to the module G.

The probe (Hall Module H) uses 3 discrete Hall elements, which allows high resolution spatial measurement and good angular accuracy ($< \pm 2^\circ$).

The Module G is a three-channel analogue electronic processing unit. It consists of three separated electronic processing units, one for each of the measurement channels X, Y and Z.

To build up a complete measurement system, the module G needs to be connected with an adequate power supply and three voltmeters and/or a data acquisition system.

Each Module G can be set as “MASTER” or “SLAVE” by setting the slide switch in a proper position. When the device is set as “MASTER” it outputs the control frequency to the SYNC terminal, otherwise, when it’s set as “SLAVE” it can receive the control frequency from the SYNC terminal. This type of operation minimises beating between the devices. One “MASTER” device can drive up to 5 “SLAVE” devices.



Figure 3. Front and back panel of the Electronics module G

Specifications:

Mechanical

Package: high mechanical strength, EMC shielded
Aluminium case 213.4mm W x 315.5mm L x 133.4mm H
(9 dm³)
Weight < 3kg

Electrical

Connector CoS (signal)	Radial BR2 bulkhead receptacle rear mount (Mating Plug, BR2 straight plug clamp 2 cores cab 4mm) Field signal X+, X-, ground shield (front side) Field signal Y+, Y-, ground shield (front side) Field signal Z+, Z-, ground shield (front side) Temperature signal BNC out (back side) Synchronization signal BNC out (back side)
Connector CoP (probe)	Lemo - EGG.2B.314.CLL - socket, panel, 14 way (back side) (Mating Plug, FGG.2B.314.CLAD92Z)
Connector AC (power)	IEC/EN 60950 compliant, 3 poles (L – N – E) (back side)

The other specifications are given in the list of specifications of the corresponding transducer.

Power

Voltage	110V/220V
Current	ca. 400/200 mA

Environmental

Temperature (operating)	+5° to +45°C
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Specifications

Unless otherwise noted, the given specifications apply to all measurement channels at room temperature (23°C) and after a device warm-up time of 30 minutes.

Parameter	Value	Remarks
Range		
▪ Maximum (full scale) magnetic flux density	± 2T (± 20 kG)	No saturation of the outputs
▪ Linear range of magnetic flux density B_{LR}	± 2T (± 20 kG)	Optimal measurement range
Accuracy		
▪ Calibration Accuracy	10 ppm	With calibration tables at const. temperature See DC Calibration and Note 1
X, Y & Z CHANNEL		
▪ Resolution	1 µT	See Note 9.
▪ Base accuracy < 2T	Better than 1% of B_{LR}	With no corrections
▪ Non-linearity NL ($B_{LR} \leq 2T$)	<0.5% of B_{LR}	See Note 4.
Sensitivity		
▪ Nominal Sensitivity to DC magnetic field	5 V/T (0.5 mV/G)	S_{NOM}
▪ Real Sensitivity, S	$ S - S_{NOM} < 0.02 \cdot S_{NOM}$	Determined during calibration
▪ Tolerance of sensitivity S_{Err}	< 0.02% of S_{NOM}	$100 \cdot S - S_{NOM} / S_{NOM}$
▪ Temperature coefficient of sensitivity	< 25 ppm /°C	at 23°C ±5°C
▪ Long-term instability of sensitivity	<1% over 10 years	
Offset		
X, Y & Z CHANNEL		
▪ Offset (@B = 0 T) V_{off} (B_{off})	< ± 3 mV (0.6 mT)	
▪ Temperature coefficient of the offset	< 10 µV/°C (2 µT/°C)	
▪ Offset fluctuation & drift (0.1 to 10Hz)	< 3 µV (0.6 µT)	Standard deviation value; see Note 6
Output Noise		
X, Y & Z CHANNEL		
▪ Noise spectral density at f=1 Hz NSD1	$\approx 1 \mu V / \sqrt{Hz}$ (0.2 µT/√Hz)	Region of 1/f noise
▪ Corner frequency f_c	< 10 Hz	Where 1/f noise = white noise
▪ Noise spectral density at f<100 Hz NSD _w	$\approx 0.5 \mu V / \sqrt{Hz}$ (0.1µT/√Hz)	Region of white noise
▪ Broad-band noise (10 Hz to fT) V_{nRMS}	< 5 µV (1 µT)	Standard deviation value; see note 7
▪ Synchronisation signal	500 kHz, TTL	

Frequency response		
0.001% error	1 Hz	Test: $B(t)=10\text{mT} \cdot \sin(2\pi ft)$
0.01% error	4 Hz	Test: $B(t)=10\text{mT} \cdot \sin(2\pi ft)$
Bandwidth f_T	100 Hz	Sensitivity decrease -3dB; see Note 11
General properties		
▪ Output voltages V_{out}	Differential	Optionally single ended. See Note 2.
▪ Planar Hall voltage V_{Planar} (at $B = 1\text{T d.c.}$)	$< 0.05\%$ of V_{Normal}	See Note 5.
▪ Output resistance	$< 100\ \Omega$, short circuit proof	
▪ Temperature output (single-ended)	$T[^\circ\text{C}] \times 50\text{mV}/^\circ\text{C}$	
▪ External synchronisation	Master/slave configuration	
▪ Operating temperature	+5° to +45°C +15° to +35°C (optimal range)	Different ranges upon request.
▪ Storage temperature	+10° to +50°C	
▪ Electromagnetic	Compliant with standard regulations	

Power supply:

SENIS' transducer *03N08C-G02T0K1M* is powered by the main power.

Recommended Accessories:

- Zero gauss chamber: ZG12
- Output cable X.Y meter: COSxx – A
- Low pass filter (see Note 12)
- Differential-to-Single-Ended Transformer

Optional Services:

DC Calibration

The calibration table of the transducer can be ordered as an option. The calibration table is an Excel file, giving the actual values of the transducer output voltages for the test DC magnetic flux densities measured by a reference NMR Tesla-meter. The standard calibration table covers the linear range of magnetic flux density $\pm B_{LR}$ in the steps of $B_{LR}/10$. Different calibration tables are available upon request. By the utilisation of the calibration table, the accuracy of DC and low-frequency magnetic measurement can be increased up to the limit given by the resolution (see Notes 1 and 6 – 10).

AC calibration

Another option is the calibration table of the frequency response. This is an excel file, giving the actual values of the transducer transfer function (complex sensitivity and Bode plots) for a reference AC magnetic flux density. The standard frequency response calibration table covers the transducer bandwidth, from DC to f_T , (in logarithmically equidistant steps). Different calibration tables are available upon request. Utilisation of the frequency calibration table allows an accuracy increase of the AC magnetic measurements almost up to the limit given by the resolution (see Notes 1 and 6 – 11).

NOTES:

- 1) The accuracy of the transducer is defined as the maximum difference between the actual measured magnetic flux density and the one given by the transducer. In other words, the term accuracy expresses the maximum measurement error. After zeroing the offset at the nominal temperature, the worst case relative measurement error of the transducer is given by the following expression:

$$\text{Max. Relative Error, } MRE = S_{err} + NL + 100 \cdot \frac{Res}{B_{LR}} \quad \text{Eq. [1]}$$

Where, S_{err} is sensitivity tolerance (relative error in percents of S), NL is the maximal relative nonlinearity error (see note 4), Res is the absolute resolution (Notes 6 - 10) and B_{LR} is the linear range of magnetic flux density.

- 2) The output of the measurement channel has two terminals and the output signal is the (differential) voltage between these two terminals. However, each output terminal can be used also as a single-ended output relative to common signal. In this case the sensitivity is approx. 1/2 of the differential output value (Remark: The single-ended output is not calibrated).
- 3) Sensitivity is given as the nominal slope of an ideal linear function $V_{out} = f(B)$, i.e.

$$V_{out} = S \cdot B \quad \text{Eq. [2]}$$

where V_{out} , S and B represent transducer output voltage, sensitivity and the measured magnetic flux density, respectively.

- 4) Nonlinearity is the deviation of the function $B_{measured} = f(B_{actual})$ from the best linear fit of this function. Usually, the maximum deviation is expressed in terms of percentage of the full scale input. Accordingly, the nonlinearity error is calculated as follows:

$$NL = 100 \cdot \frac{\left\{ \frac{V_{out} - V_{off}}{S'} \right\}_{MAX}}{B_{LR}} \text{ for } -B_{LR} < B < B_{LR} \quad \text{Eq. [3]}$$

Symbol	Description
B	DC magnetic flux density measured with a reference NMR Tesla-meter
$V_{out}(B) - V_{off}$	Corresponding to the measured transducer output voltage after zeroing the offset
S'	Slope of the best linear fit of the function $f(B) = V_{out}(B) - V_{off}$ (i.e. the actual sensitivity)
B_{LR}	Linear range of the magnetic flux density

- 5) The planar Hall voltage is the voltage at the output of a Hall transducer produced by a magnetic flux density vector co-planar with the Hall plate. The planar Hall voltage is approximately proportional to the square of the measured magnetic flux density, B^2 . Therefore, for example:

$$\left. \frac{V_{planar}}{V_{normal}} \right|_{B=2T(DC)} = 4 \cdot \left. \frac{V_{planar}}{V_{normal}} \right|_{B=1T(DC)}$$

Here V_{normal} denotes the normal Hall voltage, i.e. the transducer output voltage when the magnetic field is perpendicular to the Hall plate.

- 6) This is the 6-sigma peak-to-peak span of offset fluctuations with the sampling time of $\Delta t = 0.05s$ and total measurement time of $t = 100s$. The measurement conditions correspond to the frequency bandwidth from 0.01Hz to 10Hz. "6-sigma" signifies that for an average of 0.27% of measurement time, the offset will exceed the given peak-to-peak span. The corresponding root mean square (RMS) noise equals 1/6 of the "Offset fluctuation & drift".
- 7) Total RMS of the output noise voltage (on all frequencies) of the transducer. The corresponding peak-to-peak noise is about 6 times greater than the RMS noise. See also Notes 8 and 9.

- 8) Maximal signal bandwidth of the transducer, determined by a built-in low-pass filter with a cut-off frequency of f_T . In order to reduce the noise or to avoid aliasing, the frequency bandwidth can be limited by passing the transducer output signal through an external filter (see Notes 9 and 10).
- 9) Resolution of the transducer is the smallest detectable change of the magnetic flux density that can be measured at the output. The resolution is limited by the noise of the transducer and depends on the frequency band of interest.

The DC resolution is given by the specification “Offset fluctuation & drift” (see also Note 6). The worst-case AC resolution is given by the specification “Broad-band noise” (see also Note 7). The resolution of a measurement can be increased by limiting the frequency bandwidth of the transducer. This can be done by passing the transducer output signal through a hardware filter or by averaging the measured values. (Caution: filtering produces a phase shift, and averaging a time delay!) The RMS noise voltage (i.e. resolution) of the transducer in a frequency band from f_L to f_H can be estimated as follows:

$$V_{rmsB} \approx \left[NSD_{1/f}^2 \cdot 1Hz \cdot \ln \frac{f_H}{f_L} + 1.57 \cdot NSD_w^2 \cdot f_H \right]^{\frac{1}{2}} \quad \text{Eq. [4]}$$

Here $NSD_{1/f}$ is the 1/f noise voltage spectral density (RMS) at $f=1Hz$; NSD_w is the RMS white noise voltage spectral density; f_L is the low, and f_H is the high-frequency limit of the bandwidth of interest; and the numerical factor 1.57 is determined by a first-order low-pass filter. For DC measurements, $f_L = 1 /$ (measurement time). The high-frequency limit cannot be higher than the cut-off frequency of the built-in filter f_T : $f_H \leq f_T$. If the low-frequency limit f_L is higher than the corner frequency f_c , then the first term in Eq. (4) can be ignored. Otherwise, if $f_H \leq f_c$, then the second term can be ignored. The corresponding peak-to-peak noise voltage can be calculated according to the 6-sigma rule, i.e. $V_{nP-PB} \approx 6 \times V_{rmsB}$.

- 10) According to the sampling theorem, the sampling frequency must be at least two times higher than the highest frequency of the measured magnetic signal. The signal sampling frequency is denoted by f_{samS} . However, in order to obtain the best signal-to-noise ratio, it is useful to allow over-sampling (to avoid aliasing of high-frequency noise). To achieve the best resolution, the recommended physical sampling frequency of the transducer output voltage is $f_{samP} > 5 \times f_T$ (or $f_{samP} > 5 \times f_H$, if an additional low-pass filter is used, see Note 9). The number of samples can be reduced by averaging every N subsequent samples, $N \leq f_{samP} / f_{samS}$. When measuring fast-changing magnetic fields, one should take into account the transport delay of the Hall signals, small inductive signals generated at the connections of the Hall probe's thin cable, and the filter effect of the electronics in the E-Module. Approximately, the transducer transfer function is similar to the one for the first-order low-pass filter, with the bandwidth from dc to f_T . The calibration table of the frequency response is available as an option.
- 11) Senis low-pass filter and differential-to-single-ended transformer are designed to preserve maximal signal quality when connected to the electronic module E. They don't contribute any additional noise when they are properly connected. The low-pass filter can be used in different frequency ranges depending on the customer specific application resp. expected signal frequency.
- 12) The switching “noise” is a periodic signal at $f_{sw} = 15.625$ kHz and the related harmonics. It is due to the switching transients produced by the so-called spinning current process in the Hall elements. When performing A/D conversion of the transducer output signal, the sampling rate should be well above $2 f_{sw}$ in order to avoid aliasing of the switching noise. The switching noise can be efficiently suppressed by averaging the transducer signal over a time period $N \times 1/f_{sw}$, with N being an integer number.