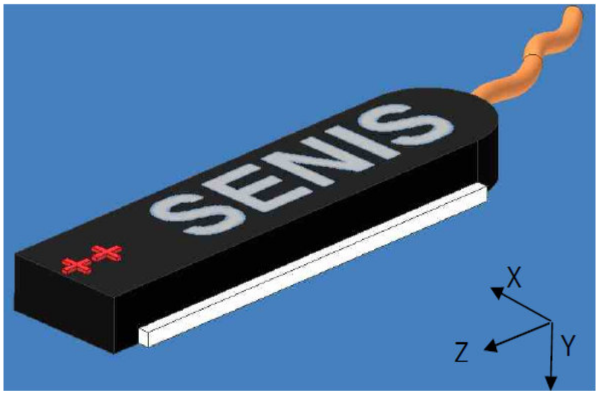
ULTRA LOW NOISE

MAGNETIC FIELD TRANSDUCER 2D-YZ



Key Features	
Calibration Accuracy	10ppm
Broad-band Noise	B_{RMS}<1µT
Offset Drift$_{0.01\text{-}0.1Hz}$	$B_{OF,RMS}$<0.4µT
Max range	± 2T
Linear range	± 1T
Probe dimensions	1.5 x 5 x 16.5 mm

Description

SENIS transducer J-YZb-20_Eb-400Hz-LN-1T is a high accuracy magnetic flux-density-to-analogue-voltage transducer with a high-level output signal for each of the two 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 Eb

To build up a complete measurement system the module E needs to be connected with an adequate power supply and 2 voltmeters and/or a data acquisition system.

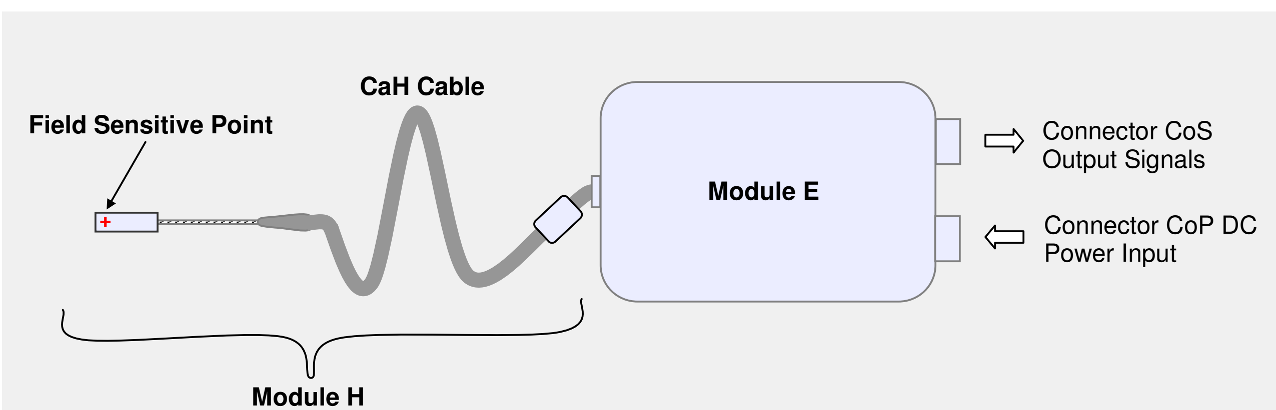


Figure 1: Schema of the SENIS low noise Hall Magnetic Field Transducer:
- Module H, consisting of the Hall Probe and the CaH Cable
- Module E, Analog electronics for signal conditioning.
Note: The Cable CaH is permanently connected to the module E.

Specifications

Unless otherwise noted, the given specifications apply to both measurement channels Y and Z at room temperature (23℃) and after a device warm-up time of 3 minutes.

Parameter	Value	Remarks
Range		
▪ Maximum (full scale) magnetic flux density	± 2T	No saturation of the outputs
▪ Linear range of magnetic flux density B_{LR}	± 1T	Optimal measurement range
Accuracy		
▪ Calibration Accuracy	10 ppm	With calibration tables at const. Temp. See DC Calibration and Note1.
▪ Resolution	1µT	See Note 9.
▪ Base accuracy	Better than 0.5% of B_{LR}	With no corrections
▪ Non-linearity NL ($B_{LR} \leq$ 1T)	<0.25% of B_{LR}	See Note 4.
Sensitivity		
▪ Nominal Sensitivity to DC magnetic field	5 V/T (0.5mV/G)	S_{NOM}
▪ Real Sensitivity, S	$\lvert S - S_{NOM} \rvert < 0.02 \cdot S_{NOM}$	Determined during calibration
▪ Tolerance of sensitivity S_{Err}	< 0.02% of S_{NOM}	$100 \cdot \lvert S - S_{NOM} \rvert / S_{NOM}$
▪ Temperature coefficient of sensitivity	< 25 ppm /℃	at 23℃ ±5℃
▪ Long-term instability of sensitivity	<1% over 10 years	
Offset		
▪ Offset (B = 0 T) V_{off} (B_{off})	< ± 1 mV (0.2mT)	
▪ Temperature coefficient of the offset	< 15µV/℃ (3µT/℃)	
▪ Offset fluctuation & drift (0.01 to 0.1Hz)	< 2µV (0.4µT)	Standard deviation value; see note 6
Output Noise		
▪ Noise spectral density at f=1 Hz NSD1	≈ 1µV/$\sqrt{Hz}$ (0.2µT/$\sqrt{Hz}$)	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	≈ 0.25 µV/$\sqrt{Hz}$ (0.05µT/$\sqrt{Hz}$)	Region of white noise
▪ Broad-band noise (10 Hz to fT) V_{nRMS}	< 5µV (1µT)	Standard deviation value; see note 7
▪ Switching noise	<10uVpp(2uTpp) @ f=15.625kHz	See notes 12
Frequency response		
0.001% error	4 Hz	Test: B(t)=150mT • sin(2πf • t)
0.01% error	10 Hz	Test: B(t)=150mT • sin(2πf • t)
Bandwidth f_T	400 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 = 1T d.c.)	< 0.05% of V_{Normal}	See note 5.

▪ Output resistance	< 100 Ohm, short circuit proof	
▪ Temperature output (single-ended)	T[°C] x 50mV/°C	
▪ 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	Documentation available upon request.

Power supply:

SENIS transducer J-YZb-20_Eb-400Hz-LN-1T can be both battery operated or powered by main power.

Recommended Accessories:

- Zero gauss chamber: ZG12
- Power supply S12-5 (±12 V) 110/220V
- Output cable X.Y meter: COXY – G
- 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 that 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:

Max. Relative Error, $M.R.E = S_{err} + NL + 100 \cdot \mathrm{Res} / B_{LR}$ Eq. [1]

SENIS GmbH, Technoparkstrasse 1, 8005 Zurich, Switzerland Phone: +41(79) 366 8756 Fax:+41(43)205 2638 Email: info@senis.ch
North America: GMW, 955 Industrial Road, San Carlos, CA 94070 Phone: +1 (650)802 8292 Fax:+1(650)802 8298 Email: sales@gmw.com

Here, S_{err} is the tolerance of the sensitivity (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 that of the differential output (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.

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

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 of this deviation is expressed in terms of percentage of the full-scale input. Accordingly, the nonlinearity error is calculated as follows:

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

Notation:	
B	Actual testing DC magnetic flux density given by 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 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:

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

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 sampling time Δt = 0.05s and total measurement time t = 100s. The measurement conditions correspond to the frequency bandwidth from 0.01Hz to 10Hz. The "6-sigma" means that in average 0.27% of the measurement time offset will exceed the given peak-to-peak span. The corresponding root mean square (RMS) noise equals 1/6 of "Offset fluctuation & drift".

7) Total output RMS noise voltage (of all frequencies) of the transducer. The corresponding peak-to-peak noise is about 6 times 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 f_T. In order to decrease noise or avoid aliasing, the frequency bandwidth may be limited by passing the transducer output signal trough 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 revealed by the output signal. 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 trough 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:

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

Here NSD_{1f} 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 comes under the assumption of using a first-order low-pass filter. For a DC measurement, f_L = 1 / (measurement time). The high-frequency limit can not be higher than the cut-off frequency of the built-in filter f_T: $f_H \le f_T$. If the low-frequency limit f_L is higher than the corner frequency f_c, then the first term in Eq. (4) can be neglected. Otherwise if $f_H \le f_c$, than the second term can be neglected. The corresponding peak-to-peak noise voltage can be calculated according to the 6-sigma rule, i. e $V_{nP\text{-}PB} \approx 6 \times V_{rmsB}$.

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. Let us denote this signal sampling frequency by f_{SamS}. However, in order to obtain the best signal-to-noise ratio, it is useful to allow for over-sampling (this way we avoid aliasing of high-frequency noise). Accordingly, for 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, $N \le f_{SamP} / f_{SamS}$. 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 Hall probe – thin cable, and the filter effect of the electronics in the E-Module. Approximately, the transducer transfer function is similar to that of a 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. When properly connected, no additional noise is introduced. 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} = 15.625Hz 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, in order to avoid aliasing of the switching noise, the sampling rate should be well above 2 f_{sw}. The switching noise can be efficiently suppressed by averaging the transducer signal over a time period N x 1/f_{sw}, N being an integer number.

13)

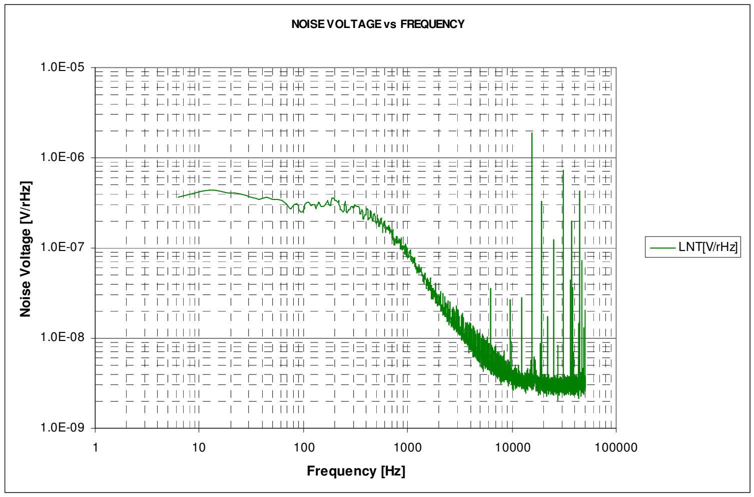


Figure 2: Voltage noise spectral density vs. frequency of the transducer output signal.

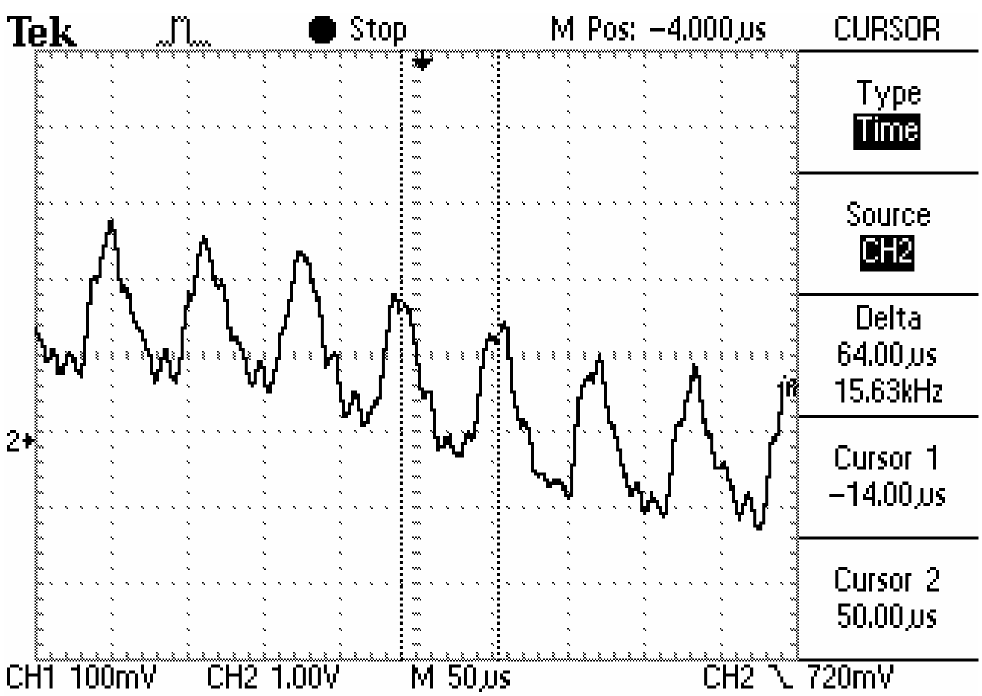


Figure 3: Switching noise in the transducer output amplified 200000 times (106dB).