SENIS transducer x-H3x-xx_E3D-2.5kHz-1.0-0.2T 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 E

To build up a complete measurement system the module E needs to be connected with an adequate power supply and 3 voltmeters.

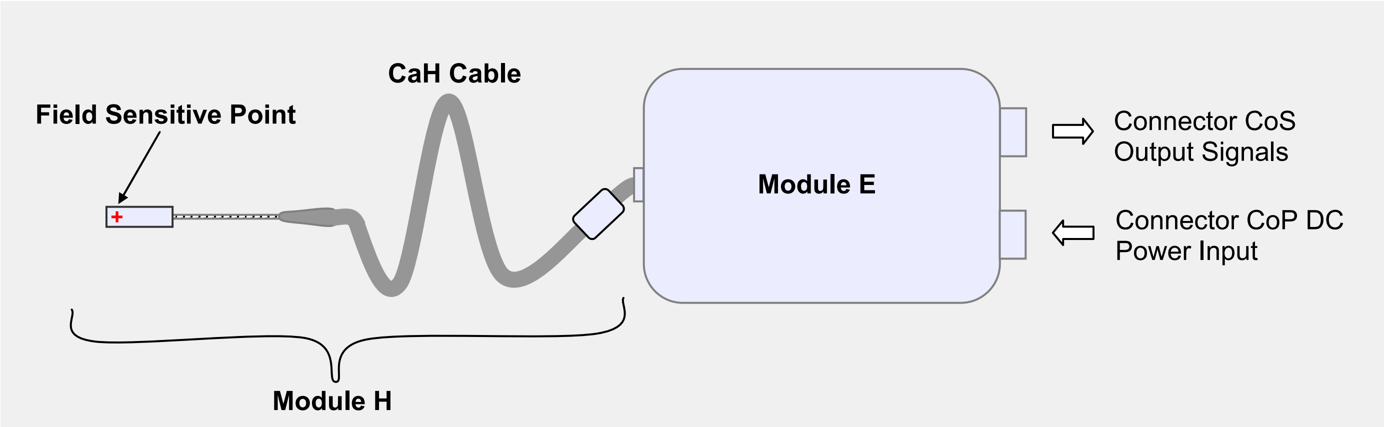

Figure 1: Schema of the SENIS high-accuracy Hall Magnetic Field Transducer:
- Module H, consisting of the Hall Probe and the CaH Cable
- Module E, Analog electronics for signal conditioning.
Note: The Cable CaH is permanently connected to the module E.

Specifications

Unless otherwise noted, the given specifications apply for all three B-measurement channels X, Y, Z at room temperature (23°C) and after a device warm-up time of 3 minutes.

Magnetic & Electrical Device Properties

Parameter	Value	Remarks
Maximum (full scale) magnetic flux density	± 0.5T	No saturation of the outputs
Linear range of magnetic flux density $\pm B_{LR}$	± 0.2T	Optimal measurement range
Accuracy	1.0% of B_{LR}	See note 1
Output voltages V_{out}	differential	See note 2
Sensitivity to DC magnetic field S	50 V/T (5 mV/G)	Differential output; see note 3
Tolerance of sensitivity S_{Err}	< 0.5% of S	$100 \cdot \lvert S' - S \rvert / S$, notes 3 and 4
Temperature coefficient of sensitivity	< 100 ppm /°C	at 23°C ±10°C
Non-linearity NL (B ≤ 0.2T)	< 0.1%	See note 4
Planar Hall voltage V_{Planar} (at B = 0.1T d.c.)	< 0.01% of V_{Normal}	See note 5
Long-term instability of sensitivity	< 1% over 10 years	
Offset (B = 0 T) V_{off} (B_{off})	< ± 5 mV (0.1mT)	
Temperature coefficient of the offset	< 0.5 mV/°C (0.01mT/°C)	
Offset fluctuation & drift (Δt = 0.05s, t = 100s)	< 2 mV_{p-p} (0.04mT_{p-p})	Peak-to-peak; see note 6

Output noise		
Noise spectral density at f=1 Hz NSD1	≈ $100\mu V/\sqrt{Hz}$ ($2\mu T/\sqrt{Hz}$)	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	≈ $40\ \mu V/\sqrt{Hz}$ ($0.8\mu T/\sqrt{Hz}$)	Region of white noise
Broad-band noise (10 Hz to f_T) V_{nRMS}	< 2 mV (0.04 mT)	RMS noise; see note 7
Resolution		See notes 6 - 10
Typical frequency response		
0.1% error	> 110 Hz	Test: $B(t) \simeq 150mT \bullet \sin(2\pi f \bullet t)$
1.0% error	> 350 Hz	
Bandwidth f_T	2.5 kHz	Sensitivity decrease -3dB; see note 11
Output resistance	< 10 Ohm, short circuit proof	
Temperature output (single-ended)	$\left[T(C^{\circ}) - (23C^{\circ} \pm 0.5C^{\circ})\right] \cdot 500 \frac{mV}{C^{\circ}}$	

Environmental Parameters		
Operating Temperature	5° to 45°C	
Storage Temperature	-20° to 85°C	
Electromagnetic	Compliant with standard regulations	Documentation available upon request.

Recommended Accessories:

- High Quality Power Supply[1)] S12-5 (±12 V, 110/220V). *Remark: To ensure the quality of measurements we strongly recommend a power supply with a good quality of the voltage output.*
- Zero gauss chamber: ZG12
- Output cable 1.5 meter: CO15 - G
- Probe support: PSB

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 the steps of f_T/10. Different calibration tables are also 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).

[1)] Switched-mode power supply: ±12V & ±5V. Ripple & noise less than $50mV_{p-p}$ (at 5V) respectively 100 mV_{p-p} (at 12V). Detailed datasheet available at SENIS.

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, $M.R.E = S_{err} + NL + 100 \cdot \mathrm{Res} / B_{LR}$ [unit: % of B_{LR}] Eq. [1]

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.

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

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

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

Notation:

B	Actual testing DC magnetic flux density given by a reference NMR Tesla-meter
$V_{out}(B) - V_{off}$	Corresponding 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:

$$\left.\frac{V_{planar}}{V_{normal}}\right|_{B=0.2T(DC)} = 4 \bullet \left.\frac{V_{planar}}{V_{normal}}\right|_{B=0.1T(DC)}$$

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. 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 $V_{nP-PB} \approx 6 \times V_{rmsB}$.

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, $N \le f_{SamP} / f_{SamS}$.

11) 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.