DESCRIPTION:

The **H3A-YZI02F-B02T0K5K** denotes a Low-Noise SENIS Magnetic Field-to-Voltage Transducer with a hybrid 2-axis Hall Probe, with Hall sensors arranged along the X-axis.

The Hybrid Hall Probe integrates two high-resolution Hall sensors with a good angular accuracy (orthogonality error < 2°) of the measurement axis of the probe and a temperature sensor.

The Hall probe is connected with an electronic box (Module E in Fig. 1). The Module E provides biasing for the Hall probe and the application of the spinning-current technique, which very effectively cancels offset, low frequency noise and the planar Hall effect.

The additional conditioning of the Hall probe output signals in the electronic box includes Hall signal amplification, high linearization, compensation of the temperature variations, and limitation of the frequency bandwidth.

The outputs of the H3A Magnetic Transducers are available at the connector CoS of the Module E: these are high-level differential voltages proportional with each of the measured components of a magnetic flux density, and a ground-referred voltage proportional with the probe temperature.

KEY FEATURES:

- **Very robust Hall Probe. The Hall sensors are glued onto a reference ceramic plate suitable for an appropriate fixing of the Probe.**
- **Hybrid 2-axis (By, Bz) Hall Probe, with two Hall sensors arranged along the X-axis.**
- **Ultra-low noise & offset fluctuation magnetic transducer, allowing very high resolution measurements (spectral density of noise down to 10 nT/$\sqrt{\text{Hz}}$)**
- **Very high linearity**
- **Magnetic transducer based on much improved offset and noise reduction technique**
- **Very low planar Hall voltage**
- **A temperature sensor on the probe for temperature compensation**

TYPICAL APPLICATIONS:

- Mapping magnetic fields
- Characterization of undulator systems
- Current sensing
- Application in laboratories and in production lines
- Quality control and monitoring of magnet systems (generators, motors, etc.)

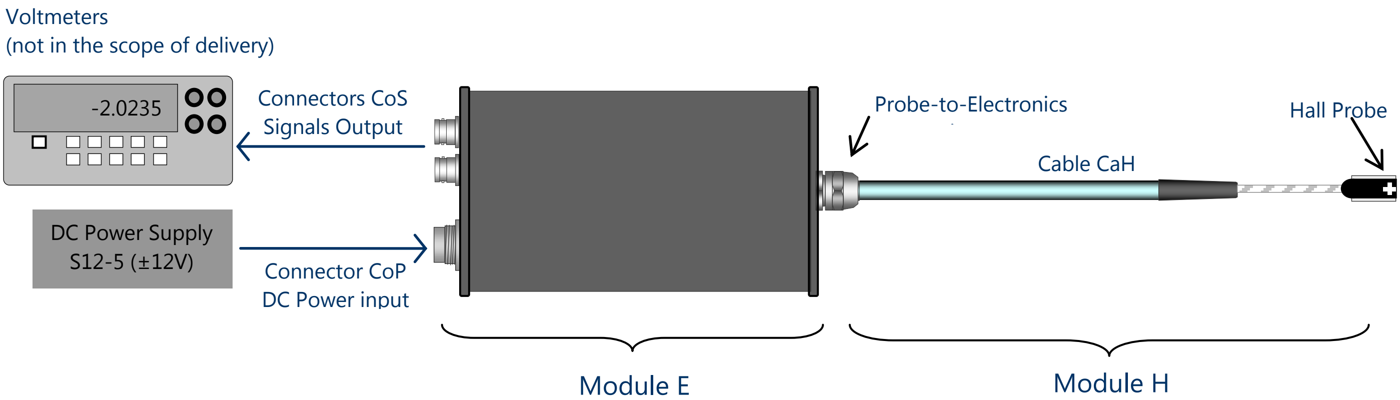
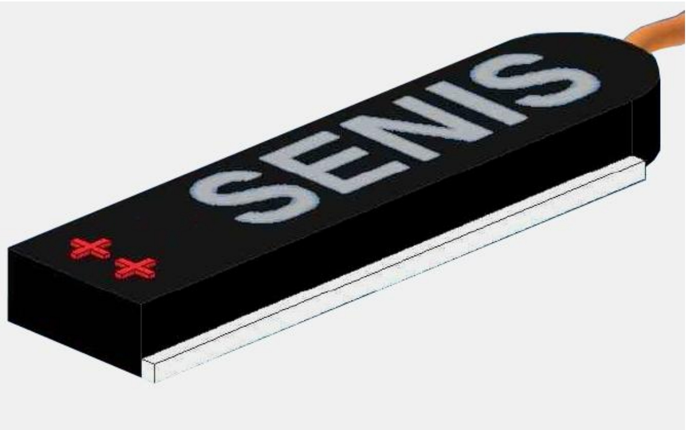


Figure 1. **Typical measurement setup with a SENIS magnetic-field-to-voltage transducer with hybrid 2-Axis Hall Probe (Module H) and Electronic (Module E, encapsulated in the box type B)**

Figure 2. **2-axis analog magnetic field transducer H3A-YZI02F-B02T0K5K**

SPECIFICATIONS (Module H):



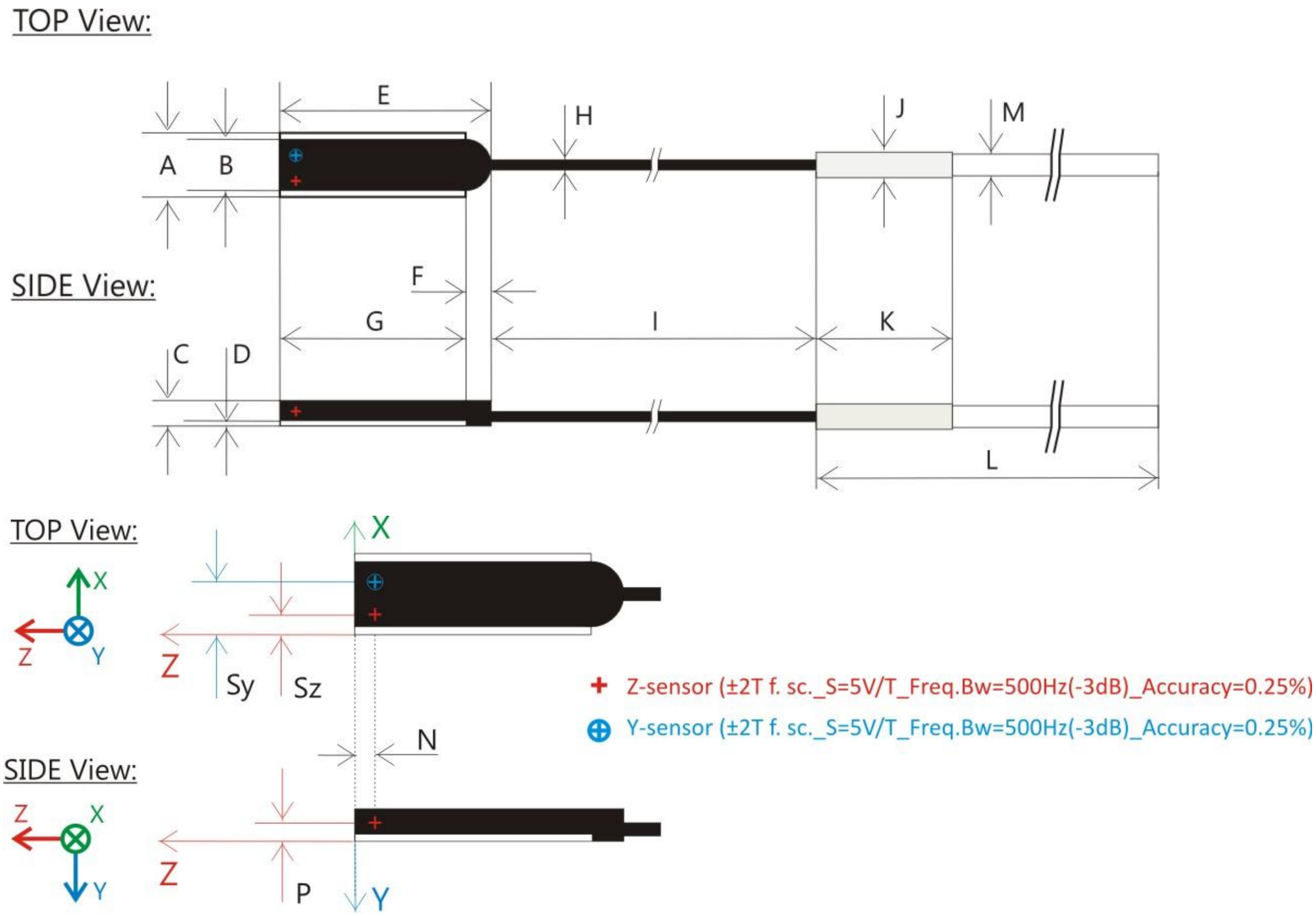
The SENIS **H3A-YZI02F** is a Two-Axis Hall-Probe System that gives an analogue voltage output for each of the two components of the measured magnetic flux density and for the probe temperature. The probe contains two very-high-resolution Hall elements arranged along the X-axis, and a temperature sensor.
The Hall sensors are embedded in the probe package and are connected to the cable. The probe package is made of a ceramic material and serves as a reference plate, suitable for appropriate positioning of the probe.

KEY FEATURES of the 2-axis YZI Hall Probe System:

- Low noise (allowing high-resolution measurements);
- Measurement of Y and Z magnetic field components with a high angular accuracy and high spatial resolution;
- Virtually no planar Hall Effect;
- Negligible inductive loops;
- The probe provides a temperature signal for an efficient compensation of temperature effects.

PROBE DIMENSIONS AND CHARACTERISTICS:

Depending on design, the probe itself can be as short as 15 mm and placed into a suitable probe holder 30 mm or longer. The sensor positions (mutual and with respect to the probe's head) remain the same in both configurations.



Hall Probe		Cable		Hall sensors positions	
Dimension	mm	Dimension	mm	Dimension	mm
A	5.0 ± 0.1	H	R 0.9 ± 0.1	N	1.25 ± 0.1
B	4.0 ± 0.1	I	200 ± 5	P	1.1 ± 0.1
C	2.0 ± 0.1	J	R 2.0 ± 0.2	Sy	3.25 ± 0.1
D	0.4	K	20 ± 1	Sz	1.25 ± 0.1
E	16.5 ± 0.1	L	2'000 ± 20		
F	R 2.5 ± 0.1	M	R 1.7 ± 0.1		
G	14.5 ± 0.1				

Figure 3. **Dimensions and tolerances of the H-module H3A-YZI02F. All measures are displayed in mm. RED cross denotes the Z-sensor, and BLUE circled-cross denotes the Y-sensor. The length of the reference ceramics can be extended to facilitate fixation and handling.**

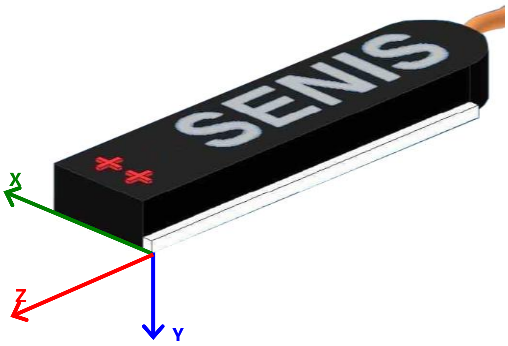


Figure 4. **Reference Cartesian coordinate system of the YZI Hall probe**

Parameter	X (mm)	Y (mm)	Z (mm)
Dimensions			
Magnetic field sensitive volume (MFSV) of the applied Hall sensors	150 x 1 x 150 µm		
Position of the centre of the Y-sensor	3.25 ± 0.1	-1.1 ± 0.1	-1.25 ± 0.1
Position of the centre of the Z-sensor	1.25 ± 0.1	-1.1 ± 0.1	-1.25 ± 0.1
Total external dimensions of the Probe	5.0 ± 0.1	2.0 ± 0.1	16.5 ± 0.1
Sensors positioning accuracy			
Mutual angular accuracy of the axes	Better than 2° (mutual orthogonality)		
Angular accuracy of the axes with respect to the reference surface	±2°, determined during calibration		
General properties			
Cable	Flexible shielded cable, ext. diameter <2mm, with a thin section near the Hall probe (see Fig. 3)		

INSTALLATION MANUAL for the YZI HALL PROBE

Although the YZP probe is very robust with respect to its size, it should be handled with special care. Considering that we deal with a high-precision device of very small dimensions, following precautions should help to avoid damage to the probe during installation and handling, and ensure that the device's accurate calibration remains preserved.

The mounting of the probe should be carried out by application of very low pressure to its head and thin wires. If the probe head is clamped, the user needs to make sure that the environment surface in contact with the reference plane of the probe is flat and covers as much of the probe reference surface as possible. Do not apply more force than required to hold the probe in its mounting.

In order to prevent rupture of the thin wires from the probe head, the user should fix and secure the probe cable in the proximity of the head. The thin wires of the flexible section of the probe need to be folded with care; repeated strong bending should be avoided.

The probe tip is fragile; it should not come into a hard mechanical contact with other objects! Take off the protective cap only if the MFSV (Magnetic Field Sensitive Volume) of the probe cannot be placed in the desired position.

Also, avoid any high pressure and bending of the transient section between the thin and the thick cables.

MAGNETIC and ELECTRICAL SPECIFICATIONS:

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

Parameter	Value	Remarks
Maximum magnetic flux density ($\pm B_{FS}$)	±2T (±20kG)	No saturation of the outputs
Linear range of magnetic flux density ($\pm B_{LR}$)	±2T (±20kG)	Fully calibrated meas. range
Total measuring Accuracy (@ $B \le \pm B_{LR}$)	0.25%	See note 1
Output voltages (V_{out})	differential	See note 2
Sensitivity to DC magnetic field (S)	5V/T (0.5mV/G)	Differential output; See note 3
Tolerance of Sensitivity (S_{err}) @ $B \le \pm B_{LR}$	0.02%	See notes 3 and 4
Nonlinearity (NL) (@ $B \le \pm B_{LR}$)	0.15%	See note 4
Planar Hall voltage (V_{planar}) @ $B \le \pm B_{LR}$	< 0.05 % of V_{normal}	See note 5
Temperature Coefficient of Sensitivity	< ±25ppm/°C (±0.0025%/°C)	@ Temperature range 23°C ± 5°C
Long-term instability of sensitivity	< 1% over 10 years	
Offset (@ B = 0T)	< ±5mV (±1mT)	@ Temperature range 23°C ± 5°C
Temperature Coefficient of the Offset	< ±10μV/°C (±2μT/°C)	
Offset fluctuation and drift (0.01 to 10Hz)	< 8μV (1.6μT)	Peak-to-peak values; See note 6
Output noise:		
Noise Spectral Density @ f = 1Hz (NSD_1)	$1\mu V/\sqrt{Hz}$ ($0.2\mu T/\sqrt{Hz}$)	Region of 1/f – noise
Corner frequency (f_C)	10Hz	Where 1/f noise = white noise
Noise Spectral Density @ f > 10Hz (NSD_w)	$0.25\mu V/\sqrt{Hz}$ ($0.05\mu T/\sqrt{Hz}$)	Region of white noise
Broad-band Noise (10Hz to f_T)	<7μV (1.4μT)	RMS noise; See note 7
Resolution		See notes 6 - 10
Typical frequency response:		
Frequency Bandwidth [f_T]	500Hz	Sensitivity decrease -3dB; Note 11
Output resistance	< 100 Ω, short circuit proof	
Temperature outputs:		
from the Hall Probe:	V_{TH} [mV] = V_{TH}(0°C) + (T[°C] x 20[mV/°C])	
from the Electronic box:	V_{TE} [mV] = V_{TE}(0°C) + (T[°C] x 20[mV/°C])	
	V_{TH} and V_{TE} are ground-referred voltages. Values V_{TH}(0°C) and V_{TE}(0°C) are determined under calibration.	

MODULE E - MECHANICAL AND ELECTRICAL SPECIFICATIONS:

Module E, type B (for 2-axis magnetic field transducers)	High mechanical strength, electrically shielded aluminium case 110 W x 230 L x 56 H mm (*see Fig. 2*) Weight < 2kg	
Connectors CoS (Radial BR2 bulkhead receptacle rear mount (mating plug, BR2 straight plug clamp 2 cores cab 4mm))	Field signal Y+, Y-, ground shielded Field signal Z+, Z-, ground shielded Temperature of the Probe (BNC) Temperature of the El. Box (BNC)	front side
HALL PROBE Connector CaH	**Fixed connection** Cable Gland MS PG7	rear side
DC Power Connector CoP DIN SFV50, 5 pole (Mating Plug, KV50), front side	Power, +12V Power, -12V Power, +5V Power common (GND)	Pin 3 Pin 1 Pin 5 Pin 2, Pin 4
DC Power	Voltage: Current:	±12V nominal, ±2% ca. 400mA

Environmental Parameters:

Operating Temperature	+5°C to +45°C	**Optimal range:** +15°C to +35°C
Storage Temperature	-20°C to +85°C	

Magnetic Flux Density (B) units (T-tesla, G-gauss) conversion:

1T = 10kG

1mT = 10G

1µT = 10mG

OPTIONS:

DC Calibration

The calibration table of the transducer can be ordered as an option. The calibration table is an Excel-file, providing the actual values of the transducer output voltage for the test DC magnetic flux densities measured by a reference NMR Teslameter. The standard calibration table covers the linear range of magnetic flux density ± 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 - Frequency Response

Another option is the calibration table of the frequency response. This is an Excel file, providing 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).

SENIS 2-Axis Ultra-low noise Hall transducer H3A-YZI02F-B02T0K5K is applicable in the B-frequency range from DC to 500Hz (-3dB point; here B being the density of the measured magnetic flux). In addition to the Hall voltage, at high B–frequencies also inductive signals are generated at the connection probe-thin cable. Moreover, the probe, the cable and the electronics in the E-module behave as a low-pass filter. As a result, the transducer has the "complex" sensitivity of the form:

$$S = S_H + jS_I$$

Here:

- S_H represents sensitivity for the output signal in phase with the magnetic flux density (that is the real part of the transfer function);
- S_I is the sensitivity with the 90° phase shift with respect to the magnetic flux density (i.e., the imaginary part of the transfer function).

Calibration data can be ordered for S_H and S_I for both Y and Z measurement axes (as an option). This allows the customer to deduce accurate values of the measured magnetic flux density at even high frequencies by an appropriate mathematical treatment of the transducer output voltage V_{out}.

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:

$$\text{Max. Relative Error: } M.R.E. = S_{err} + NL + 100 \times Res / B_{LR} \quad [\text{unit: \% of } B_{LR}] \qquad \text{Eq. [1]}$$

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) The ***sensitivity*** is given as the nominal slope of an ideal linear function $V_{out} = f(B)$, i.e.

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

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

4) The ***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:

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

Notation:

B = Actual testing DC magnetic flux density given by a reference NMR Teslameter

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

Tolerance of sensitivity can be calculated as follows:

$$\text{Tolerance of sensitivity} = 100 \times |S' - S| / S \qquad \text{Eq. [4]}$$

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. Therefore, for example:

$$\left.\frac{V_{planar}}{V_{normal}}\right|_{@B} = 4 \times \left.\frac{V_{planar}}{V_{normal}}\right|_{@B/2} \quad \text{Eq. [5]}$$

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:

$$V_{nRMS\text{-}B} \simeq \sqrt{NSD_{1f}^2 \times 1Hz \times \ln\left(\frac{f_H}{f_L}\right) + 1.22 \times NSD_W^2 \times f_H} \quad \text{Eq. [6]}$$

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 *1.22* comes under the assumption of using a second-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. (6) can be neglected; otherwise: if the high-frequency limit f_H is lower than the corner frequency f_C, than the second term in Eq. (6) can be neglected. The corresponding peak-to-peak noise voltage can be calculated according to the *"6-sigma"* rule, i. e., $V_{nP\text{-}P\text{-}B} \approx 6 \times V_{nRMS\text{-}B}$.

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 8). The number of samples can be reduced by averaging every N subsequent samples, $N \leq f_{samP} / f_{samS}$.

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. Approximately, the transducer transfer function is similar to that of a second-order Butterworth low-pass filter, with the bandwidth from DC to f_T. The filter attenuation is -40db/dec. (-12db/oct.).

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 x 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 x $1/f_{sw}$, with N being an integer number.