DESCRIPTION:

The **I1B-0ZG02F-J.1T0M4J** is a very high frequency Magnetic Field-to-Voltage Transducer with integrated 1-axis Hall-Coil Probe. It measures magnetic fields along the longitudinal direction of the probe system.

The Probe contains a CMOS integrated circuit, which incorporates a Hall device, miniature planar coil, and temperature sensor. The integrated magnetic field sensing elements occupy very small area (250µm x 250µm), which provides very high spatial resolution of the probe.

The Probe is connected with an electronic box (Module E in Fig. 1). The Module E provides biasing, fusion of the Hall and coil signals, offset cancelling, amplification, compensation of the temperature variations, and limitation of the frequency bandwidth.

The outputs of the I1B magnetic field transducer are available at the connector CoS of the Module E: this is a high-level differential voltage proportional to the measured Z-axis component of a magnetic flux density.

KEY FEATURES:

- **Very high frequency bandwidth (up to 0.5 MHz)**
- **Integrated Hall Sensor and Planar Coil**
- **Axial probe system, round, measures magnetic fields normal to the front surface of the probe**
- **Very low noise and offset fluctuations**
- **Very high linearity**
- **Negligible inductive loops on the Probe**

TYPICAL APPLICATIONS:

- **Measurements of magnetic fields produced by high frequency solenoids**
- **Current sensing**
- **Development of magnet systems**
- **Mapping magnetic fields (DC and AC)**
- **Application in laboratories and in production lines, etc.**

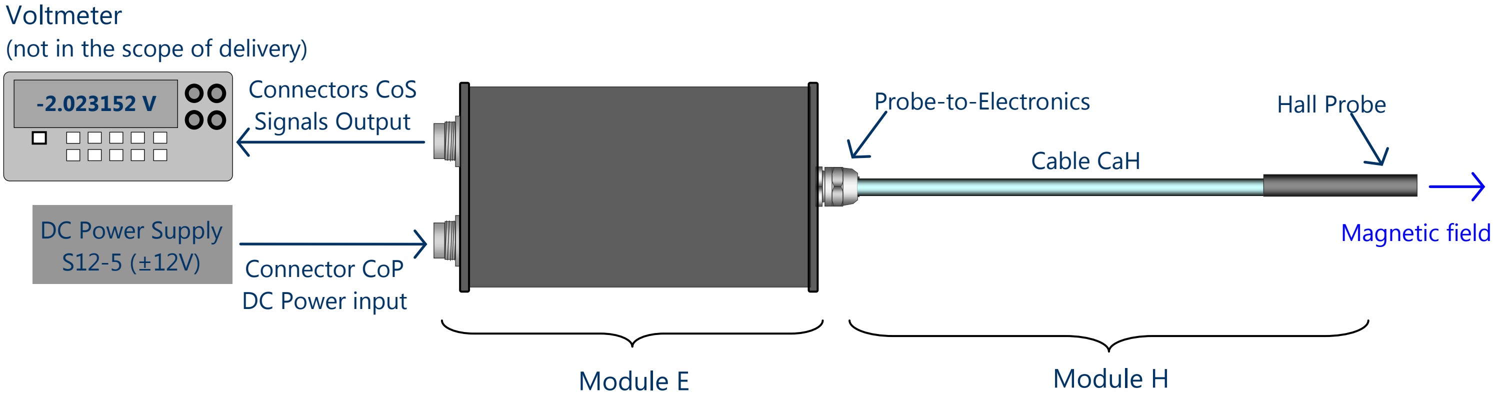


Figure 1. **Typical measurement setup with a SENIS magnetic-field-to-voltage transducer with integrated Hall Probe (Module H) and Electronic (Module E)**

Figure 2. **Single-axis analog magnetic field transducer type I1B-0ZG02F-J.1T0M4J**

SPECIFICATIONS (Module H):

Hall Probe 0ZG for SENIS' I1B analog magnetic field transducers is a very robust, single-chip integrated 1-axis Hall-Probe. It measures magnetic fields perpendicular to the front plane (Bz) of the probe.

The Probe contains a CMOS integrated circuit, three groups of mutually orthogonal Hall elements. The integrated Hall elements occupy very small area (250 x 250 µm), which provides very high spatial resolution of the probe.

The sensor chip is embedded in the probe package and connected to the CaH cable, which makes this probe both mechanically and electrically very robust.

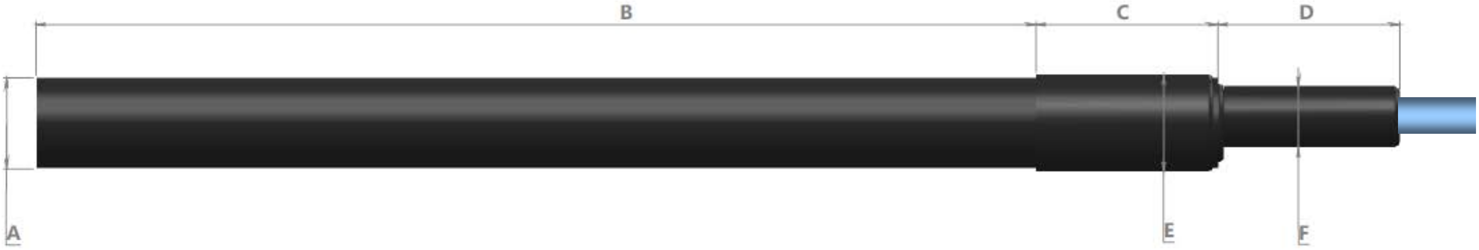
The outputs of the Hall Probe are high-level analog voltages proportional to the measured axial component (Bz) of a magnetic flux density.

KEY FEATURES OF THE I1A-0YA HALL PROBE SYSTEM

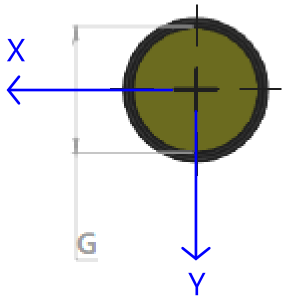
- **Very robust Hall Probe. The chip is mounted into a non-conductive rigid cylindrical stem, which is the best choice for high frequency AC fields measurements (no eddy currents generated in the material when it is in AC fields). Rigid probe stem also provides very good protection for the delicate Hall sensor.**
- **Integrated CMOS 1-axis (Bz) Hall Probe**
- **Very low noise and offset fluctuations**
- **Very high spatial resolution (0.25 x 0.25 x 0.25mm^3)**
- **Virtually no planar Hall effect**
- **Negligible inductive loops on the Probe**
- **Suitable as Z-axis (0Z) Hall Probe (axial measurement direction)**

PROBE DIMENSIONS

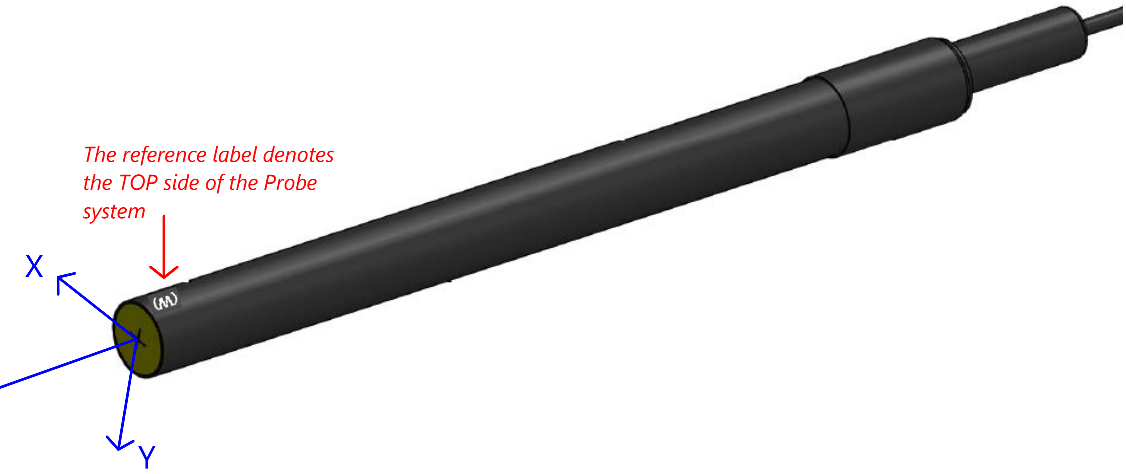
(A) Side View:



(B) Front View:



(C) Isometric View:



Dimension	mm
A	Ø 15.5 ± 0.2
B	170 ± 2
C	30 ± 2
D	30 ± 2
E	Ø 16.5 ± 0.5
F	Ø 10.0 ± 0.5
G	Ø 14.5 ± 0.2

Figure 3. **Dimensions of 0ZG Hall probe system: (A) Side view; (B) Front view; (C) Isometric view. The reference Cartesian coordinate system of the probe head is marked with the blue arrows. Magnetic field sensitive point (MFSP) is marked with the black cross on the front side of the probe stem.**
NOTE: The voltage output of the Probe system will be POSITIVE when the magnetic field vector is oriented along the POSITIVE Z-direction.

Dimension	X [mm]	Y [mm]	Z [mm]
Magnetic field sensitive volume (MFSV)	0.25	0.25	0.25
Position of the center of MFSV (corresponding to the reference Cartesian coordinate system of the Probe, see *Fig. 3*)	0.0 ± 0.2 mm	0.0 ± 0.2	-1.5 ± 0.3
Total Probe external dimensions	Length: 200 mm Diameter: 15.5 mm		
Angular accuracy of the sensor positioning	±2° with respect to the reference (front) surface		
CaH Cable	Shielded flexible cable, 2m length, ext. diameter 6.3±0.2 mm		
Total length of the CaH cable:	▪ Standard: 2 m (Probe notation: **0ZG02F**) ▪ Optional: xx m (Probe notation: **0ZGxxF**) *Various cable lengths are available upon request.*		

USER GUIDE FOR THE I1B-0ZG HALL PROBE SYSTEM

The I1B-0ZG is an axial probe system which has the Hall sensor mounted perpendicular to the longitudinal axis of the probe and measures magnetic fields parallel to the probe axis.

Silicon Hall sensor chip is mounted on a very thin flexible substrate, which is connected to the thick shielded cable with strongly twisted thin wires, on such a way providing almost negligible inductive loops along the probe stem.

The flex substrate and connection wires are mounted into a thin shallow channel along the rigid probe holder.

Probe holder is made of a fully non-conductive rigid material (fiberglass), which enables measurement of high-frequency AC fields without inducing eddy currents.

Although the I1B-0ZG 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:

- Do not expose Hall probe tip to a rapid temperature changes.
- Avoid sudden strikes of the probe tip at solid objects (very fragile silicon sensor chip is mounted very close (only 1.5 mm) to the front side of the Probe).
- Avoid any strong pressure on the labeled side of the Probe in order to prevent damages of the thin flex wires:

MAGNETIC and ELECTRICAL SPECIFICATIONS:

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

Parameter	Value	Remarks
Maximum (full scale) magnetic flux density	±0.1T (±1 kG)	No saturation of the outputs
Linear range of magnetic flux density ($\pm B_{LR}$)	±0.1T (±1 kG)	Optimal, fully calibrated meas. range
Total measurement Accuracy	better than 0.1% @B ≤±0.1T	See note 1
Output voltages (V_{out})	differential	See note 2
Sensitivity to DC magnetic field (S)	100 V/T (10 mV/G)	Differential output; See note 3
Tolerance of sensitivity (S_{err}) (@ $B \le \pm B_{LR}$)	< 0.03% of S	$100 \times \lvert S' - S \rvert / S$; See notes 3 and 4
Nonlinearity (NL)	better than 0.05% @ B≤±0.1T	See note 4
Planar Hall voltage (V_{planar}) (@ $B \le \pm B_{LR}$)	< 0.01 % of V_{normal}	See note 5
Temperature coefficient of sensitivity	< ±100 ppm/°C (±0.01 %/°C)	@ temperature range 23°C ± 10°C
Long-term instability of sensitivity	< 1% over 10 years	
Offset (@ B = 0T)	< ±3 mV (±30 μT)	@ temperature range 23°C ± 5°C
Temperature coefficient of the offset	< ± 0.5 mV/°C (±5 μT/°C)	
Offset fluctuation & drift (Δt = 0.05s, t = 100s)	< 0.5 $mV_{p\text{-}p}$ (5 $\mu T_{p\text{-}p}$)	RMS value is approximately 80 μV_{RMS} (0.8 μT_{RMS}); See note 6
Output noise		
Noise Spectral Density @ f > 100 Hz (NSD_W)	4 $\mu V/\sqrt{Hz}$ (40 $nT/\sqrt{Hz}$)	Region of **white** noise
Broad-band Noise (100 Hz to 500 kHz) ($V_{nRMS\text{-}B}$)	< 2 mV_{RMS} (20 μT_{RMS})	RMS noise; see note 7
Resolution		See notes 6 - 10
Typical frequency response		
Test conditions: $B = 10mT \times \sin(2\pi ft)$; see below OPTION: "AC Calibration-Frequency Response"		
Frequency Bandwidth [f_T]	> 500 kHz	-3dB point; See note 11

MECHANICAL and ELECTRONICS SPECIFICATIONS (Module E):

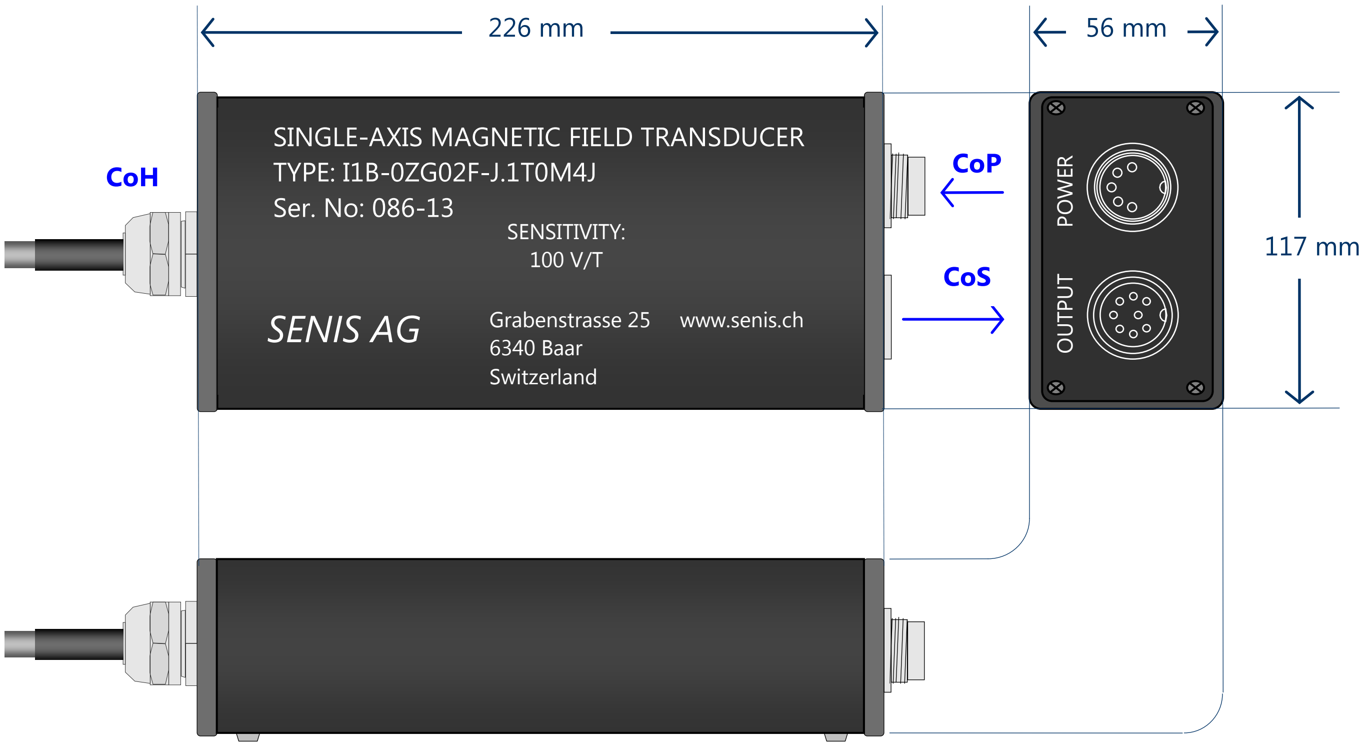


Figure 5. **Structure and dimensions of the single-channel analogue processing module (type J)**

Module E	High mechanical strength, electrically shielded aluminium case 117 W x 226 L x 56 H mm; Weight < 1kg (see *Fig. 5*)	
Output Signals Connector CoS DIN KFV81, 8 poles (Mating plug SV81)	Field signal Y+, Y- Signal common (GND)	Pins 5 and 4, respectively Pin 8
Power Connector CoP DIN SFV50, 5 poles (Mating plug KV50)	Power, +12V Power, -12V Power common (GND)	Pin 3 Pin 1 Pin 2
Hall Probe Connector CoH	**Fixed probe connection:**	Cable gland MS PG11
DC Power	Voltage: Max. Ripple: Current:	±12V nominal, ±2% 100 mVpp ca. ±100 mA

Environmental Parameters:		
Operating Temperature	+5°C to +45°C	NOTE: Maximum allowed operating temperature of the HALL probe and Cable is +70°C.
Storage Temperature	-20°C to +85°C	

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

1 T = 10 kG   1 mT = 10 G   1 µT = 10 mG

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 Single-Axis Hall transducer I1B-0ZG02F-J.1T0M4J is applicable in the B-frequency range from DC to 500 kHz (-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 the axial (longitudinal) component (Bz) 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:

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

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 $B_{\text{measured}} = f\,(B_{actual})$ 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:

$$\left.\frac{V_{planar}}{V_{normal}}\right|_{@\,B = 0.1T} = 4 \bullet \left.\frac{V_{planar}}{V_{normal}}\right|_{@\,B = 0.05T} \qquad \text{Eq. [5]}$$

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:

$$V_{nRMS\text{-}B} \approx \sqrt{1.57 \times NSD_W^2 \times f_H} \qquad \text{Eq. [6]}$$

Here NSD_w is the RMS white noise voltage spectral density, 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. The high-frequency limit can not be higher than the cut-off frequency of the built-in filter f_T: $f_H \leq f_T$. 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) 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 Butterworth low-pass filter, with the bandwidth from DC to f_T. The filter attenuation is -20 db/dec. (-6 db/oct.). The calibration table of the frequency response is available as an option.