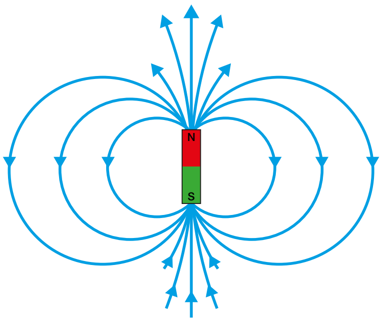
mainSENSOR: disturbance sources and important data

1. In general

The aim of this TechNote is to describe the behaviour of magneto-inductive sensors (MDS) in practice and share valuable information. The main focus of this report is on the measurement principle as well as the influcence of disturbances. In order to obtain a reliable and optimal measuring signal these influences have to be minimised. You will find further data and information in our catalogue.

2. Measurement principle

The MDS sensor evaluates the distance between the permanent magnet and a sensor element. As shown in the illustration beside, the field lines of the magnet extend into the air and meet, at a certain distance, the sensor element. The further the sensor element and the magnet are apart from each other, the lower the magnetic field strength at the sensor will be. It is exactly this relation that is used to determine the distance. To receive the best possible signal the magnet has to be moved frontally along the sensor axis. However, lateral or parallel measurements are also possible (see 3.3).



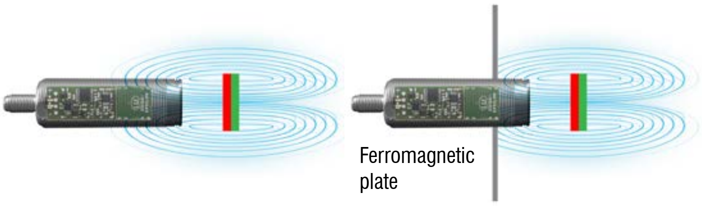
The measuring principle behind the sensor is based on extending an eddy current sensor by adding a magnetically sensitive element. Due to the counteracting physical effects, this results in a linear relationship between distance and output signal (self-linearisation). To achieve the full stroke the magnetic field strength has to vary between approximately 2.5mT and 22.5mT. This is ensured by the Neodym magnets (Br=1.1) provided. Nevertheless, other magnets can also be used.

3. Disturbance sources

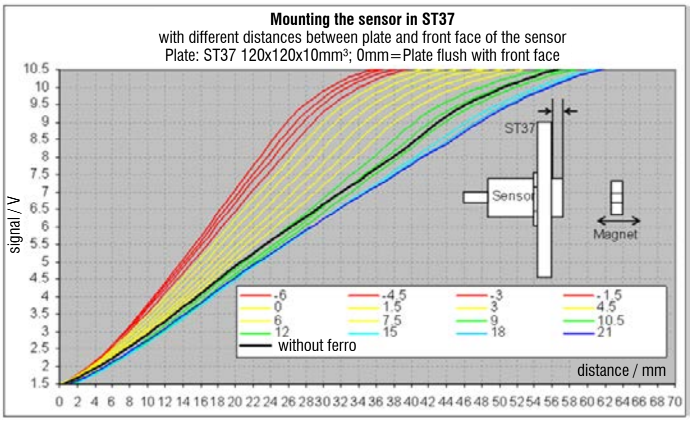
Every disturbance of the magnetic field at the sensor has, of course, an influence on the measuring signal. On the one hand, main disturbances are external magnetic fields (other magnets or electric motors), on the other hand a distraction/shielding of the magnetic field in use by ferromagnetic materials (e.g. assembly material). Consequently, these disturbances result in changes in linearity, resolution, offset and measuring range.

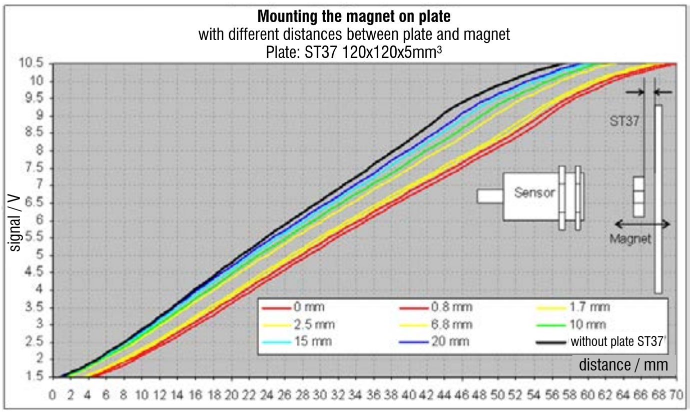
3.1. Installation conditions

Ferromagnetic materials attract magnetic field lines and thus change their course. In addition, these materials cannot be penetrated by them. Attention must be paid to this, particularly when installing the sensor and the magnet. The field line profile used in the following example is aimed at showing how the path of the magnetic field lines is changed by ferromagnetic materials which may also affect the measuring signal.



In the diagram below, signals are presented that depend on the signal characteristics of the sensor's overhang or underhang in a ferromagnetic plate. The second diagram shows the influence of the distance between the steel plate and the magnet on the output signal.

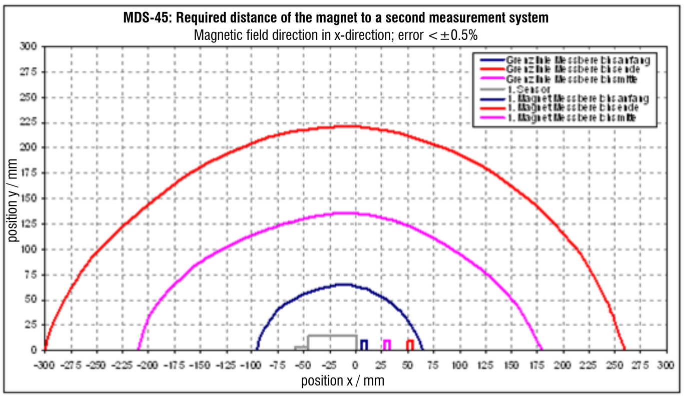

Mounting the sensor in ST37
with different distances between plate and front face of the sensor
Plate: ST37 120x120x10mm³; 0mm=Plate flush with front face


Mounting the magnet on plate
with different distances between plate and magnet
Plate: ST37 120x120x5mm³

Only non-ferromagnetic materials, such as aluminium should be used when assembling and mounting the sensor. If non-ferromagnetic stainless steels are used, attention must be paid to the fact that due to mechanical treatment a magnetisation may take place or the pieces can turn slightly ferromagnetic which can, however, be reversed by thermal treatment (annealing).

3.2. External magnetic fields

Not only a change in the magnetic field line course but also additional magnetic fields have a great influence on the measuring signal, as these are superimposed on the magnetic field in use. Thus, the targets of neighbouring sensors, magnetic fields of electric motors or other magnetic fields may exert influence on the signal. Therefore, the sensors should be installed in such a way that they are not exposed to any additional magnetic fields. Furthermore, it is important to pay attention to the indicated distance between two neighbouring MDS sensors in order to keep their influence on one another to a minimum. An example of this is shown on the basis of a 45mm magnet in the illustration beside. The distances that should be adhered to change depending on the strength of the magnet in use.



The Earth's magnetic field

The strength of the Earth's magnetic field in Germany ranges from 0.045mT to 0.049mT, and from 0.030mT to 0.065mT world-wide. This magnetic field is superimposed on the magnetic field of the target and can move the characteristic curve of the sensor slightly, depending on the orientation of the sensor to the Earth's magnetic field

3.3. Orientation of the sensor to the magnet

The signal of the sensor is defined from 2.0V to 9.6V (4.0mA to 19.2mA). The starting point of 2V corresponds, depending on the type, to a mechanical offset of 2 to 5mm between the sensor edge and the start of measuring range.

However, this point can vary due to manufacturing tolerances and the tolerances of the magnet. It is therefore recommended that you set the offset by positioning the sensor or the magnets in such a way that the zero point of the measurement is at 2.0V. You will find further information in the assembly instruction and the catalogue. The slope of the characteristic curve is also subject to tolerances. The slope can vary by about 1% FSO if the magnet is replaced and repeated mechanical adjustment is performed on the 2 V-point.

Deviation of the magnet to the sensor axis

As already mentioned, the magnet has to move along the sensor axis in order to produce a linear signal. A lateral offset will have a greater or lesser influence, depending on the distance of the magnet. It is possible to distinguish between two extreme cases: a lateral offset across and an offset along the sensor element.

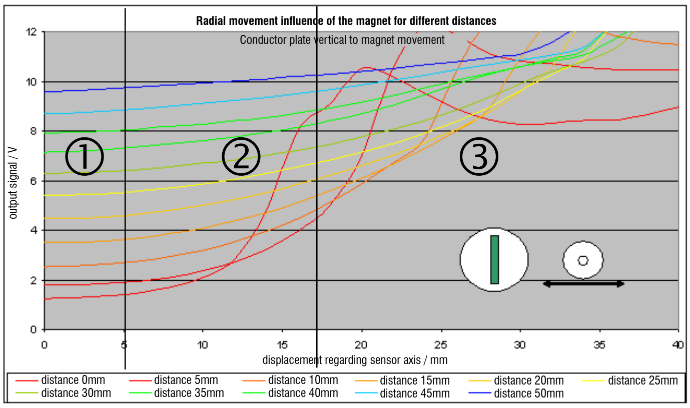
Offset of the magnet -

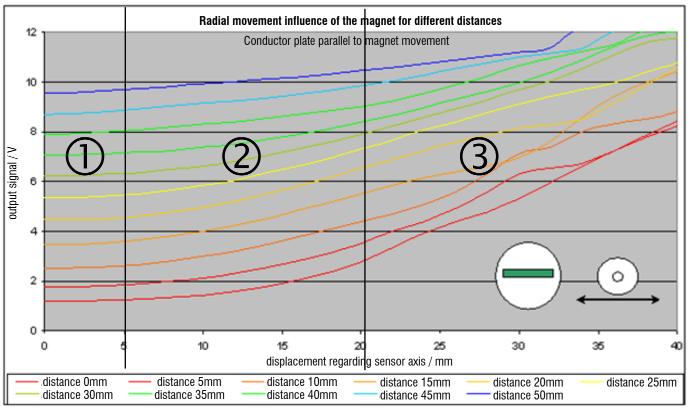
The two diagrams can be divided into 3 groups.

① Slight lateral displacement:
measurement without any major influences

② Medium lateral displacement:
characteristic curve changed significantly,
however, measurement is still possible

③ Major lateral displacement:
appropriate measurement is impossible





Comparability – for sensors with a cylindrical housing only

One important point in achieving comparability between different measurements is the orientation of the sensor. It must be ensured that the sensor element inside the sensor is always aligned identically in relation to the magnet. This can be verified by the wrench flats at the rear end of the sensor. The sensor element is perpendicular (M30/M18) or parallel to the wrench flats. This is especially crucial when the magnet is laterally offset.

Standard characteristic

Characteristic differing from data sheet

Pre-tensioning of the sensor

Pre-tensioning of a magneto-inductive sensor means to specifically use the influence of ferromagnetic materials on the output signal as described in 3.1. During this process the distance between the sensor and the permanent magnet is constant and the measurement is made on a moving ferromagnetic object. As this effect, however, is not as pronounced as the actual measuring effect the measuring range diminishes to only a few millimetres. The above-mentioned self-linearisation is thus also avoided. Consequently, the deviation from the linearity increases significantly unless the linearity is adjusted afterwards. For this sort of use several arrangements are possible; by placing the magnet inside the sensor better results can be achieved for OEM projects.

🟥 magnet

⬜ ferromagnetic object

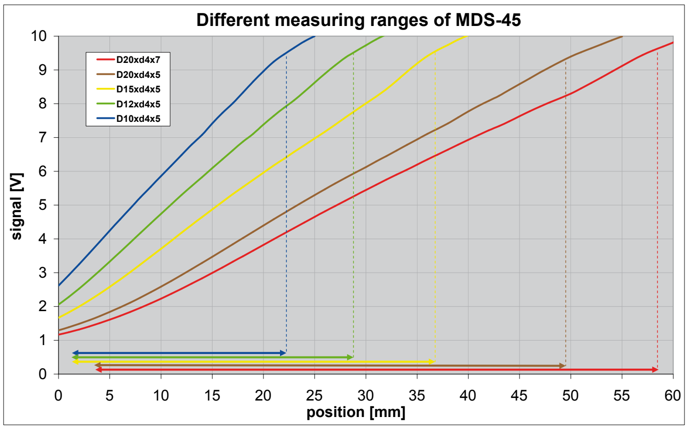
Shadowing

Direct measurement

Speed measurement (only customised sensors)

4. Changing the measuring range

The measuring range and the output signal can be changed by using different magnets.



D20xd4x7
MR: 55mm

D20xd4x5
MR: 45mm

D15xd4x5
MR: 35mm

D12xd4x5
MR: 27mm

D10xd4x5
MR: 20mm

5. Useful information

Transport regulations

When transporting magnetic materials, IATA Packing Instruction 902 must be observed. According to this regulation, the transport of the magnets with the attached transport protection is not restricted. The maximum field strength determined at a distance of 2.1m is less than 0.159A/m (0.002 Gauss) and no significant compass deviation (> 0.5 degrees) can be detected.

Connector types

The connector types used are from the series Binder 718 (M8x1). Upon request, there are different connector types available for certain types or serial applications.

Materials

- MDS-45-M30/M18/M12:

Housing:	stainless steel (type 1.4404)
Nuts:	stainless steel (type 1.4571)

- MDS-45-M18-HP

Housing:	stainless steel (type 1.3964; Nitronic HS50)

- MDS-45-K:

Housing:	Hotmelt (Thermelt® 867)
Sleeves:	brass, nickel-plated

- Supply and connection cables:

Body:	thermoplastic polyurethane (TPU)
Gasket:	plastic FPM/FKM
Cable:	polyurethane, halogen-free
Union cap nut:	metal, CuZn, nickel-plated

Response time

The time delay between input and output is constantly 40μs (tested at 50Hz – 3KHz; sinusoidal exitation).

6. Information regarding permanent magnets

NdFeB magnets in high vacuum

The magnetic characteristics of these sintered magnets are not influenced by the negative pressure of the high vacuum and can therefore be used safely. However, these magnets allow some gas diffusion. For light gases, especially hydrogens, NdFeB magnets are like sponges. Furthermore, H_2 gas which is often used for leak detecting destroys the magnets. Alternatively, the magnet can be installed in a pressure-resistant, non-ferromagnetic housing.

Influence of temperature and aging

(extract from an article by the Magnetfabrik Bonn 01/2008, MFB Praxis)

When used in typical applications permanent magnets [...] are exposed to variations in temperature throughout their working life which have an impact on the magnetic characteristics. Different kinds of stress have to be distinguished in this regard, such as cyclical stress, long-term stress etc. Although producers of materials for permanent magnets make material characteristics for different temperatures available, the information provided about relevant impacts with regard to the different kinds of stress is insufficient. Particularly when applying sensors it is of fundamental importance regarding the system setup to understand the processes which cause the magnets to weaken over time and temperature. [...]

The characteristics of all magnetic materials show a more or less great dependence on the ambient temperature. Physically, the influence of the temperature is completely described via the demagnetisation curve depending on the temperatures. As the demagnetisation curves are most of the time reduced to the parameters remanence B_R, coercive field strengths H_{CB} and H_{CJ} as well as the maximum energy product $(BH)_{max}$, the producers of materials for magnets document in general the suitable coefficients of the linear change with the temperature. [...] On the Magnetfabrik Bonn's website under the area "products", the magnetic parameters and the demagnetisation curves at different temperatures can be downloaded.

For the user, the physical material description does often not provide the practical information which is needed for the evaluation of their application. Frequently, the question of how the magnetic field of a permanent magnet changes at a fixed position under the influence of time and temperature is much more important. At this point, qualitatively different impacts occur which are described in the following. All three effects appear together and therefore have to be seen as a whole.

Reversible influence

Almost proportionally to the remanence and independent of the type of magnetisation and the form of the magnet, the magnetic field changes reversibly along with the temperature. As this reversible change is approximately linear, i. e. it corresponds to a constant increase and decrease per degree Celcius, for the description a parameter which complies approximately with the coefficient α (BR) is sufficient. Example: If α(BR) = 12% / 100 K, this means that the magnetic field changes by 0.12% with every degree Celcius with regard to the environmental temperature.

Irreversible losses due to temperature

Concerning the rare-earth magnet materials with increasing temperature not only the remanence but also the coercive field diminishes, i. e. the two coefficients α(BR) and β(HcJ) are negative. As far as hard ferrites are concerned, however, the coercive field diminishes at low temperatures, i. e. β(HcJ) is positive. The coercive field describes the stability towards a demagnetisation, i. e. it may occur that the rare-earth magnets demagnatise partially at high temperature and the hard ferrites at low temperature. **This leads to a change in the magnetic field as soon as the respective temperature is reached for the first time. This loss cannot be compensated by reaching the original temperature and is therefore irreversible.** Due to the decrease of the magnetisation a self-demagnatising field is created which leads to the fact that the weakening stabilises itself. Repeated heating up or cooling down at the same temperature does not or only slightly cause further decrease. Contrary to the reversible field change the description of the irreversible losses is more complex. They are not only dependant on the material of the magnet but also on the form of the magnet and the sort of magnetisation as well as superimposed external fields.

Irreversible losses due to time

In case of repeated temperature cycles or long-term storage it can be observed, over very long periods of time, that concerning rare-earth materials progressing irreversible demagnetisation losses occur.

These are partially caused by a delayed thermal demagnetisation as well as by a chemical change of the material. The delayed thermal demagnetisation follows a law by Arrhenius, i. e. the progress happens logarithmically according to the storage time. By means of the logarithmical dependance the loss can already be proved almost completely only a few minutes to hours afterwards. Further change over the next days and month is only very small. However, the magnetic field strength of some materials show also a stronger progressing decrease. This decrease has other physical causes and is for example due to slow chemical but continued decomposition at high temperature. [...]