(19) DANMARK

(10) **DK/EP 2823260 T3**

Patent- og Varemærkestyrelsen

(12) Oversættelse af europæisk patentskrift

(51) Int.Cl.: *G 01 D 5/14 (2006.01)* *G 01 D 5/244 (2006.01)*

(45) Oversættelsen bekendtgjort den: **2017-08-28**

(80) Dato for Den Europæiske Patentmyndigheds bekendtgørelse om meddelelse af patentet: **2017-07-26**

(86) Europæisk ansøgning nr.: **13711727.1**

(86) Europæisk indleveringsdag: **2013-03-06**

(87) Den europæiske ansøgnings publiceringsdag: **2015-01-14**

(86) International ansøgning nr.: **GB2013000090**

(87) Internationalt publikationsnr.: **WO2013132207**

(30) Prioritet: **2012-03-08 GB 201204066**

(84) Designerede stater: **AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR**

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(54) Benævnelse: **MAGNETISK INDKODNINGSAPPARAT**

(56) Fremdragne publikationer:
WO-A2-2010/139964
US-A- 4 595 991
US-A- 5 726 445
US-A1- 2011 218 760

DESCRIPTION

[0001] The present invention relates to magnetic encoder apparatus for measuring the position of a readhead relative to a magnetic scale. In particular, the present invention relates to improved magnetic encoder apparatus in which the need to match the pitch of the magnetic scale to the pitch of the magnetic sensor elements of the readhead is avoided.

[0002] Magnetic encoders are known. US4595991 describes encoder apparatus in which a scanning unit comprises multiple scanning elements for reading a measuring scale. The number of scanning elements required per period of scale is based on the bandwidth characteristic of the scanning signals. For example, a preferred embodiment describes providing six scanning elements per period of scale. The scanning signals are subjected to Fourier analysis and a pair of Fourier coefficients that describes the fundamental waveform component of the periodical analogue signals are calculated. These Fourier coefficients are said to provide harmonic-free periodic signals from which incremental position measurements can be determined. Encoders of the type described in US4595991 have the disadvantage that careful matching of the pitch of the magnetic scale to the pitch of the magnetic sensor elements is required.

[0003] WO2010/139964 describes an encoder that measures scale pitch as part of an extrapolated position measurement process. US2011/0218760 describes an encoder in which a pitch correction technique is performed.

[0004] According to a first aspect of the present invention, there is provided magnetic encoder apparatus that comprises; a magnetic scale that produces a periodically repeating magnetic pattern, a plurality of magnetic sensor elements for reading the magnetic scale, the plurality of magnetic sensor elements producing a plurality of sensor signals, and an analyser for analysing the plurality of sensor signals to provide a measure of the position of the magnetic sensor elements relative to the magnetic scale, the analyser being arranged to use the plurality of sensor signals to assess the period of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements, characterised in that the magnetic scale comprises a series of alternating first magnetised regions and second magnetised regions, the first magnetised regions being of the opposite magnetic pole to the second magnetised regions, wherein the centres of the first magnetised regions are spaced apart from one another by a fixed interval and each first magnetised region has a first width or a second width to thereby encode a data bit, the data bit taking a first value if the first magnetised region has the first width and a second value if the first magnetised region has the second width.

[0005] The present invention thus provides encoder apparatus comprising a plurality of magnetic sensor elements (e.g. an array of Hall sensors) that each output a sensor signal describing the strength of the magnetic field present at the sensor element. The plurality of magnetic sensor elements can thus be used to read or image an associated magnetic scale that comprises a periodically repeating magnetic pattern (e.g. an array of regions of alternating magnetisation direction). An analyser is also provided for analysing the plurality of sensor signals to provide a measure of the position of the magnetic sensor elements relative to the associated magnetic scale. Instead of assuming a certain (fixed) number of sensor elements per period of the associated magnetic scale, the analyser of the apparatus of the present invention is arranged to use the plurality of sensor signals to assess the period of the periodically repeating magnetic pattern that has been sensed by the plurality of magnetic sensor elements. This assessment may comprise calculating the period of the periodically repeating magnetic pattern and/or determining whether the sensed period differs from the expected period (e.g. due to misalignment of the sensor elements and the scale). Advantageously, the pitch of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements is different to the pitch of magnetic sensor elements. As explained in more detail below, the analyser may use Discrete Fourier transformation based methods to perform such analysis.

[0006] Unlike prior art systems of the type described in US4595991, apparatus of the present invention does not require there to be an integer number of magnetic sensor elements per scale period. In other words, the pitch of the magnetic sensor elements does not have to be matched to the pitch of the periodically repeating magnetic pattern of the magnetic scale. It should be noted that the apparatus of the present invention would operate if there were provided an integer number of magnetic sensor elements per scale period, but this is not a requirement. As explained below, the apparatus of the present invention has been found to be especially advantageous for use in rotary encoder systems in which the magnetic scale comprises radially extending magnetic segments and therefore produces a magnetic field with an effective pitch that increases with radius. The tight mounting tolerances previously required to ensure the pitch of the magnetic field pattern matches the pitch of the plurality of magnetic sensor elements are thus avoided.

[0007] Advantageously, the analyser assesses the period of the periodically repeating magnetic pattern by determining the number of periods of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements. In other words, the number of periods of the magnetic pattern that occur over the spatial extent of the plurality of sensor elements is found by the analyser from the plurality of sensor signals. Preferably, the number of periods is found to the nearest integer value. For example, it may be established that N periods of the magnetic pattern occur over the length of a linear array of sensor elements, where N is an integer. In other words, the spatial frequency of the repeating magnetic pattern can be found.

[0008] The analyser may analyse the plurality of sensor signals using any suitable mathematical technique. The analyser may comprise a processor for implementing the required technique. Advantageously, the analyser performs Fourier analysis on the plurality of sensor signals. The Fourier analysis preferably comprises the use of one or more discrete Fourier transforms. The Fourier analysis preferably assesses the period of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements. In particular, performing Fourier analysis on the plurality of sensor signals preferably allows the calculation of the amplitude of a fundamental sinusoidal component and/or one or more harmonics thereof.

[0009] The spatially varying magnetic field sensed by the plurality of sensors and output to the analyser via the plurality of sensor signals may thus be analysed using a Fourier based technique. The Fourier based technique can be used to describe the spatially varying magnetic pattern sensed by the sensor elements in terms of a fundamental (sinusoidal) component and higher order harmonics of that fundamental component. For example, Fourier analysis may be performed using a fundamental sinusoidal component having a spatial period substantially equal to the spatial extent of the plurality of sensor elements. The fundamental component would then describe a magnetic pattern having a period equal to the spatial extent of the plurality of sensor element. For example, if the sensor elements are provided in a linear array the fundamental sinusoidal component may have a period substantially equal to the length of the linear array. In such an example, the first harmonic (H1) would correspond to two periods of a magnetic pattern over the spatial extent of the plurality of sensor elements, the second harmonic (H2) to three periods, the third harmonic (H3) to four periods etc. It would, of course, be possible to define a fundamental component having any desired spatial frequency and the spatial frequency is only matched to the spatial extent of the plurality of sensor elements for convenience.

[0010] The analyser may monitor the amplitude of the fundamental sinusoidal component or any one or more of the harmonics. A change in amplitude of the fundamental sinusoidal component or any one or more of the harmonics may be used to indicate that there has been a change in the period of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements. In other words, the analyser may assess the period of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements by measuring the amplitude of the fundamental sinusoidal component or of any one or more of the harmonics.

[0011] In a preferred embodiment, the analyser performs Fourier analysis on the plurality of sensor signals to calculate the relative amplitude of a plurality of the harmonics. The relative amplitude of the different harmonics may then provide an indication of the alignment of the plurality of sensor elements relative to the scale.
For example, eight periods of a magnetic pattern may be formed over the spatial extent of the plurality of sensor elements when the sensor elements are correctly aligned relative to the scale. In such an example, the amplitude of the seventh harmonic (H7) would be substantially greater than the amplitude of other harmonics (H5, H6, H8, H9 etc). If any misalignment occurred, the amplitude of the H7 component would reduce and the amplitude of other components would increase. In particular, the amplitude of one of the neighbouring harmonics (e.g. H6 or H8) would increase. Monitoring the relative amplitude of a plurality of the harmonics (e.g. the H6/H7 and H7/H8 amplitude ratios) thus allows the period of the periodically repeating magnetic pattern to be assessed. There can then be a correction applied (e.g. a recalculation of the period of the periodically repeating magnetic pattern to be used in the Fourier analysis) or mechanical realignment of the sensor elements and associated scale.

[0012] The apparatus of the present invention may be used to read a magnetic scale that encodes only incremental position information. In particular, the analyser may be used to extract phase information from the plurality of sensor signals. This phase information may be used to calculate any incremental movement of the plurality of magnetic sensor elements relative to the magnetic scale. For example, the analyser may generate phase quadrature signals (e.g. sine and cosine signals) that can be analysed (e.g. interpolated) to extract incremental position information. The analyser may perform such interpolation to provide incremental position data or it may just output one or more signals (e.g. phase quadrature signals) for interpolation. If the analyser analyses the plurality of sensor signals using a Fourier technique, at least one Fourier coefficient may be calculated that describes the phase of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements. The at least one Fourier coefficient calculated by the analyser may be used to calculate the incremental position information, such as phase quadrature signals, that describe any change in relative position of the magnetic sensor elements and the magnetic scale.

[0013] The apparatus of the present invention is preferably used to read an associated magnetic scale that also encodes absolute position information. For example, the associated magnetic scale may comprise, as part of the periodically repeating magnetic pattern, certain scale marking having different magnetic strengths that are used to encode different data bits. The analyser may thus be arranged to calculate the phase of the periodically repeating magnetic pattern and to determine, for each period of the pattern, the strength of the magnetic pattern sensed by the plurality of magnetic sensor elements at a predetermined phase angle. The strength of the magnetic field at certain points along the magnetic scale can thus be established, thereby allowing the relevant data bits to be extracted. In a preferred embodiment, the magnetic field strength of the plurality of signals may be found at a phase angle that corresponds to the amplitude maxima of the magnetic pattern. In other words, the analyser may establish the period and pitch of the magnetic field pattern and thereby determined the location of the peaks (maxima) in magnetic field that are associated with the centre of each first magnetised regions. The magnetic field strength at each maxima may then be analysed (e.g. compared to a threshold) to determine the pattern encoded in the magnetic scale and thereby extract the encoded data bits.

[0014] The plurality of magnetic sensor elements are conveniently arranged to read an associated magnetic scale comprising a series of alternating first magnetised regions and second magnetised regions. Absolute data is preferably encoded in the magnetic scale by providing first magnetised regions of at least a first type (e.g. a first width) and a second type (e.g. a second width) that generate different magnetic field strengths. Further details of suitable magnetic scale are outlined below. Advantageously, the predetermined phase angle used by the analyser allows the magnetic field strength of each first magnetised region to be assessed. This preferably enables the analyser to determine the presence of a first magnetised region of a first type or a second type. The values of the encoded data bits can thus be extracted by the analyser.

[0015] Advantageously, the plurality of magnetic sensor elements are arranged to simultaneously read a plurality of first magnetised regions of an associated scale. The analyser may also be arranged to determine a plurality of data bits (i.e. from the first magnetised regions that have been read) that form a codeword. The codeword may encode information about the absolute position of the plurality of magnetic sensor elements relative to the associated scale.

[0016] The apparatus also includes the magnetic scale. As described above, the magnetic scale preferably comprises a series of alternating first magnetised regions and second magnetised regions. In other words, the first and second magnetised regions alternate with one another. The first and second magnetised regions are magnetised in different directions. Advantageously, the first magnetised regions are of the opposite magnetic pole to the second magnetised regions. For example, the first magnetised regions may comprise north poles (N) and the second magnetised regions may comprise south poles (S), or vice versa. In this manner, a periodically repeating magnetic field pattern is generated that can be measured by the magnetic sensor elements and used to generate incremental position information. The centres of the first magnetised regions are spaced apart from one another by a fixed interval. The fixed interval may comprise a fixed distance interval in the case of a linear scale or a fixed angular interval in the case of radial scale. The magnetic scale encodes data bits by including first magnetised regions of at least a first type and a second type. The first type and second type of first magnetised region generates different magnetic field strengths. The magnetic field strength associated with each first magnetised region is thus used to extract encoded position information.

[0017] The first and second type of first magnetised region may be the same physical size but magnetized differently. Advantageously, the first magnetised regions of the first type comprise magnetised regions of a first width. First magnetised regions of the second type comprise magnetised regions of a second width. In this example, the first width is different to the second width. Varying the width (rather than controlling the strength of material magnetisation) is preferred because it is much easier to magnetise the scale material to saturation and control the size of the magnetised marking compared with partially magnetising parts of the material. First magnetised regions of the first type (e.g. of a first width) generates a magnetic field of a first strength and thereby encode a first data bit value. First magnetised regions of the second type (e.g. of a second width) generates a magnetic field of a second strength and thereby encode a second data bit value. In this manner, the width of the first magnetised region encodes a data bit, the data bit taking a first value if the first magnetised region has a first width and a second value if the first magnetised region has a second width. As explained above, the analyser may assess the magnetic field strength of each first magnetised region to determine the presence of a first magnetised region of a first type (e.g. first width) or a second type (e.g. second width).

[0018] Although the examples provided herein describe binary (base-2) systems (e.g. the first and second data bit values can be defined as a "0" or a "1") it should be noted that the first magnetised regions may be provided as three or more different types to encode information in a number system of a higher base.

[0019] The magnetic scale preferably comprises linear magnetic scale comprising a linear array of alternating first magnetised regions and second magnetised regions. The first and second magnetised regions of the scale are preferably rectangular segments.

[0020] The magnetic scale may comprise a radial magnetic scale comprising a series of radially extending first magnetised regions and second magnetised regions. In other words, the magnetic scale may be provided as a disk or ring having the first and second magnetised regions formed on or in its surface. The magnetised regions may be substantially wedge shaped. Advantageously, the centres of the first magnetised regions are located at substantially constant angular intervals.

[0021] The plurality of magnetic sensor elements are preferably provided as a linear array. The linear axis of the linear array may be aligned with the long axis of the scale. Assuming such alignment is adequately maintained, the pitch of the magnetic pattern will be substantially invariant along the length of the linear array of magnetic sensor elements. If, however, such a linear array of magnetic sensor elements is used to read a radial scale then the pitch of the magnetic field pattern generated by the magnetic scale will vary as a function of the radial location of the linear array and may also vary (especially for scales of smaller radius) along the length of the array. As explained above, the analyser is preferably arranged to use the plurality of sensor signals to calculate the period of the periodically repeating magnetic pattern sensed by the plurality of magnetic sensor elements. This allows the linear array of magnetic sensor elements to be placed at different radial locations because the period of the periodically repeating magnetic pattern can be established. In addition, the analyser may also apply a compensation factor or weighing to the sensor signals to compensate for the radial distribution of the first and second magnetised regions.

[0022] The plurality of magnetic sensor elements preferably comprise an array of Hall sensor elements. The Hall sensor elements may be arranged to measure the component of magnetic field perpendicular to the surface of the substrate.
The spacing between the magnetic sensor elements is preferably known. The plurality of magnetic sensor elements (e.g. Hall sensor elements) are preferably equidistantly spaced apart from one another. The plurality of magnetic sensor elements may be provided on a common substrate (e.g. on a chip). Preferably, at least four sensor elements are provided per scale period (although there is no need for this to be an integer value).

[0023] The apparatus may be configured in any suitable way. For example, the plurality of magnetic sensor elements may be provided within a readhead. The readhead may also include the analyser. The analyser may comprise a micro-processor. The analyser may be provided on the same chip or substrate as the magnetic sensor elements. Alternatively, the analyser may be provided in a separate interface. The interface may be connected to the readhead by an interface cable.

[0024] The present invention will now be described, by way of example only, with reference to the accompanying drawings in which;

Figure 1 shows an encoder readhead and a radial magnetic scale,

Figure 2 shows the encoder readhead of figure 1 with a cut-away view through the radial magnetic scale,

Figure 3 shows an encoder readhead and a linear magnetic scale,

Figure 4 shows a cross-section view of the linear magnetic scale of figure 3,

Figure 5 shows the magnetic field profile generated by the linear magnetic scale of figure 3,

Figure 6 shows the magnetic field strength measured by the encoder readhead when placed over a part of the linear magnetic scale of figure 3,

Figure 7 illustrates how the period of the magnetic pattern shown in figure 6 can be determined using Fourier analysis,

Figure 8 shows how absolute data encoded in the magnetic scale can be extracted, and

Figures 9a to 9c show the change in relative amplitudes of Fourier components arising from misalignment of a radial scale.

[0025] Referring to figures 1 and 2, angular encoder apparatus of the present invention is illustrated. The apparatus include a readhead 2 and a radial magnetic scale 4 attached to a steel ring 5. The readhead 2 comprises a sensor chip 6 comprising a linear array of fifty-three Hall sensor elements. Processing electronics 7 are also provided on the readhead. The radial magnetic scale 4 comprises alternating regions that are magnetised in different directions; these will be termed North pole (N) and South pole (S) regions. As explained in more detail below, the centres of the North pole regions are equidistantly spaced apart from one another and the magnetic scale thus provides a periodically varying magnetic field profile that can be analysed to provide incremental position data. The North pole regions are also provided in two different widths to allow absolute position data to be encoded. A first width encodes a logical "0" and a second width encodes a logical "I". In this manner, both incremental and absolute position information can be encoded in, and extracted from, the magnetic scale.

[0026] Figure 3 shows angular encoder apparatus of the present invention that includes the readhead 2 and a linear magnetic scale 10.

[0027] Figure 4 shows a cross-section of a part of the linear magnetic scale 10. The scale 10 comprises a rubber magnetic band 12 supported by a steel substrate 14. The up-arrows 16 and down-arrows 18 indicate the direction of magnetization of the alternating regions of the band 12. For convenience, the differently magnetised regions will be referred to herein as the

North pole (N) and South pole (S) regions. The magnetized regions are of different widths, but the distance between the centres of neighbouring North pole regions is the substantially constant distance P. Additionally, the North pole regions are provided in two widths, namely narrow regions 20 of width L_0 and wide regions 22 of width L_1. The narrow regions 20 indicate the state of logical "0", whilst the wide regions 22 indicate a logical "'1". The widths of the South pole regions comply with the requirement to provide a substantially constant distance between two neighbouring centres of the North pole regions.

[0028] Referring to figure 5, the normal component of magnetic field density B_n in Tesla is shown at a distance of 0.3mm above a length of linear scale is shown. In this example the distance (P) between the centres of neighbouring North pole regions is 0.9mm. The different magnetic field strength associated with the different widths of North pole region can be seen from the different heights of the maxima as shown in the figure.

[0029] Figure 6 shows the magnetic field strength as measured by the fifty-three Hall sensors of the above described readhead 2 when placed above a section of linear magnetic scale.

[0030] Figure 7 shows the sinusoidally varying component 60 of the magnetic field pattern calculated from the magnetic field strength using a Discrete Fourier transformation based process. In particular, the amplitude and phase of the sinusoidally varying component 60 of the periodically repeating signal 62 is calculated as will be explained in more detail below.

[0031] In this example, there are found to be 8 periods of the magnetic field pattern spatially distributed across the fifty-three Hall sensors of the readhead. There are thus 6.625 sensors provided per period of the magnetic pattern. In terms of Fourier analysis, the magnetic pattern of eight periods that covers the length of the array of Hall sensors can be termed the seventh harmonic (H7) of the fundamental sine wave; the fundamental sine wave comprising a single period over the array of Hall sensors.

[0032] The amplitude and phase of the signal that corresponds to the magnetic pattern can thus be calculated by the expressions:

$$S_{SIN} = \sum_{i=0}^{52} S_i \cdot Sin(\frac{i \cdot 2\pi \cdot 8}{53}) \qquad (1a)$$

$$S_{COS} = \sum_{i=0}^{52} S_i \cdot Cos(\frac{i \cdot 2\pi \cdot 8}{53}) \qquad (1b)$$

where S_i is the sensor signal produced by the i^{th} Hall sensors.

[0033] The coefficients

$$Sin(\frac{i \cdot 2\pi \cdot 8}{53})$$

and

$$Cos(\frac{i \cdot 2\pi \cdot 8}{53})$$

can be calculated in advance, so can be written as constants ks_i and kc_i. The S_{SIN} and Scos expressions thus become:

$$S_{SIN} = \sum_{i=0}^{52} ks_i \cdot S_i \quad (2a)$$

$$S_{COS} = \sum_{i=0}^{52} kc_i \cdot S_i \,. \quad (2b)$$

[0034] Amplitude and phase can then be found using the following equations:

$$Amplitude = \sqrt{S_{SIN}^2 + S_{COS}^2} \quad (3)$$

$$Phase = ArcTan(\frac{S_{SIN}}{S_{COS}}) \quad (4)$$

[0035] Figure 8 illustrates how, once the period and phase of the fundamental component 60 has been found, the strength of the sensed magnetic field 62 at each maxima of the fundamental component 60 can be extracted. The magnitude of each maxima in the sensed magnetic field 62 is related to the width of each North pole region of the scale 10. As shown in figure 8, narrow North pole regions produce a low maxima 70 whilst the wide North pole regions produce a higher maxima 72.

[0036] The data in figure 8 can then be decoded. In this example, the code word extracted is "00111111". This code word is then found in a Look-up table (LUT) and converted into a coarse absolute position. The phase information from equation 4 can also be analysed to provide a fine position that is added to the coarse position. An accurate absolute positional measurement can then be generated.

[0037] Figure 9a illustrates an output from Fourier analysis of a periodically repeating signal 62 of the type shown in figure 7. In particular, the amplitude of the fundamental and the first nineteen harmonics thereof are plotted. It can be seen that the seventh harmonic (H7) has the highest amplitude. This H7 signal is also the signal 60 shown in figure 7 that is used in the calculation of the Sine and Cosine signals from which incremental positions are calculated.

[0038] If the readhead is reading an annular scale, then the period of the sensed magnetic pattern will alter as the readhead is moved radially back and forth relative to the scale ring.

[0039] Figure 9b shows the effect of moving the readhead radially inwards (i.e. towards the centre of the scale ring). In this example, the magnetic period sensed by the readhead reduces (i.e. there are more periods falling across the 53 Hall sensors) and hence the amplitude of the eighth harmonic component (H8) increases whilst the amplitudes of H6 and H7 decrease.

[0040] Figure 9c shows the effect of moving the readhead radially outwards (i.e. away from the centre of the scale ring). In this example, the magnetic period sensed by the readhead increases (i.e. there are fewer periods falling across the 53 Hall sensors) and hence the amplitude of the sixth harmonic component (H6) increases whilst the amplitudes of H7 and H8 decrease.

[0041] It can thus be seen that readhead alignment relative to the scale can be measured by observing the H7/H6 and H7/H8 ratios. In particular, the readhead can be moved radially back and forth until the amplitude of the H7 signal is maximised so that the desired eight periods of the magnetic field pattern spatial distributed across the fifty-three Hall sensors of the readhead. Such correct alignment then ensures that the Sin and Cosine signals generated from the H7 signal provide reliable incremental position information.

[0042] It should be noted that, instead of physically moving the readhead, it would also be possible to recalculate the number of periods of the magnetic pattern sensed by the Hall array and adjust the coefficients used in equations 1a, 1b and 2 accordingly. Furthermore, it should be remembered there is also no need to provide an integer number of periods of the magnetic pattern over the length of the Hall sensor array.

[0043] It has also been found that using a linear array of Hall sensors to read a radial scale produces radial distortions in the waveforms at the ends of the array.

[0044] It has been found that the ks_i and kc_i coefficients used to generate the Sine and Cosine signals can be modified in order to compensate for the radial distortion. In particular, modified ks'_i and kc'_i coefficients can be calculated taking into account the radial distribution of the first and second magnetic regions using the expressions:

$$ks'_i = Sin\left(\frac{2\pi \cdot r}{P} \cdot ArcTan\left(\frac{x_i}{r}\right)\right) \quad (5a)$$

$$kc'_i = Cos\left(\frac{2\pi \cdot r}{P} \cdot ArcTan\left(\frac{x_i}{r}\right)\right) \quad (5b)$$

where P is the period of the scale, r is the radius of the ideal position of the readhead and x_i the distance of the i^{th} sensor from the centre of the chip. In the present example, the Hall sensors are spaced 0.15 mm apart from one another and x_i = (i-26)*0.15 mm (where 26 is the index of the central sensor on the chip and i ranges from 0 to 52). The values of ks'_i and kc'_i can be calculated in advance.

[0045] Taking the corrections of equations 5a and 5b into account the Sine and Cosine expressions become;

$$S_{SIN} = \sum_{i=0}^{52} ks'_i \cdot S_i \quad (6a)$$

$$S_{COS} = \sum_{i=0}^{52} kc'_i \cdot S_i \quad (6b)$$

[0046] Additionally, applying a so-called window function (using w_i coefficients) to equations 6a and 6b can further improve the amplitude and phase information thereby reducing the error when interpolating those signals.

$$S_{SIN} = \sum_{i=0}^{52} w_i \cdot ks'_i \cdot S_i \qquad (7a)$$

$$S_{COS} = \sum_{i=0}^{52} w_i \cdot kc'_i \cdot S_i \qquad (7b)$$

[0047] There are numerous window functions that could be applied; for example, Hann, Gauss, Triangular, Hamming functions etc.

[0048] The values of w_i can be calculated in advance as well so both coefficients w_i and kc_i (for linear scale) or w_i and kc'_i coefficients (for angular scale) can be merged into one series of coefficents w_i'. Equations 3 and 4 provided above can then be used to generate corrected amplitude and phase information.

[0049] The skilled person would appreciate that the above examples describe specific ways of implementing the invention and that various alternatives would be possible.

REFERENCES CITED IN THE DESCRIPTION

Patent documents cited in the description

- US4595991A [0002] [0002] [0006]
- WO2010139964A [0003]
- US20110218760A [0003]

Patentkrav

1. Magnetisk indkodningsapparat (2), omfattende;

en magnetskala (4;10) der producerer et periodisk gentagende magnetmønster,

en flerhed af magnetsensorelementer til læsning af magnetskalaen (4;10), idet flerheden af magnetsensorelementer producerer en flerhed af sensorsignaler, og

en analysator (7) til at analysere flerheden af sensorsignaler for at tilvejebringe en måling af positionen af magnetsensorelementerne i forhold til magnetskalaen, analysatoren (7) er indrettet til at anvende flerheden af sensorsignaler til at bedømme perioden af det periodiske gentagne magnetmønster registreret af flerheden af magnetsensorelementer,

kendetegnet ved at magnetskalaen (4;10) omfatter en serie af vekslende første magnetiserede regioner (16) og anden magnetiserede regioner (18), idet de første magnetiserede regioner (16) er af modsat magnetisk pol i forhold til de anden magnetiserede regioner (18), hvor centrene af de første magnetiserede regioner (16) er adskilt med afstand fra hinanden med et fast interval (P) og hver første magnetiserede region har en første bredde (20) eller en anden bredde (22) for derved at indkode en databit, databit'en tager en første værdi hvis den første magnetiserede region har den første bredde (20) og en anden værdi hvis den første magnetiserede region har den anden bredde (22).

2. Apparat ifølge krav 1, hvor analysatoren (7) bedømmer perioden af det periodiske gentagne magnetmønster ved at bestemme antallet af perioder af det periodisk gentagne magnetmønster registreret af flerheden af magnetsensorelementer.

3. Apparat ifølge et hvilket som helst af de foregående krav, hvor analysatoren (7) bedømmer perioden af det periodiske gentagne magnetmønster registreret af flerheden af magnetsensorelementer ved udførelse af Fourier-analyse på flerheden af sensorsignaler for at beregne amplituden af en fundamental sinusformet komponent og/eller én eller flere oversvingninger deraf.

4. Apparat ifølge krav 3, hvor analysatoren (7) udfører Fourier-analyse på flerheden af sensorsignaler for at beregne den relative amplitude af en flerhed af oversvingninger, den relative amplitude tilvejebringer en indikation af indstillingen af flerheden af sensorelementer i forhold til skalaen.

5. Apparat ifølge et hvilket som helst af de foregående krav, hvor analysatoren (7) beregner mindst en Fourier-koefficient fra hvilken trinvis voksende positionsinformation beregnes der beskriver en hvilken som helst ændring i den relative position af magnetsensorelementerne og den magnetiske skala.

6. Apparat ifølge et hvilket som helst af de foregående krav, hvor analysatoren (7) er indrettet til at beregne fasen af det periodisk gentagne magnetmønster registreret af flerheden af magnetsensorelementer og til at bestemme, for hver periode af det af det periodisk gentagne magnetmønster, styrken af magnetmønsteret registreret af flerheden af magnetsensorelementer ved en forudbestemt fasevinkel.

7. Apparat ifølge krav 6, hvor den forudbestemte fasevinkel tillader den magnetiske feltstyrke at blive bedømt for at bestemme om hver første magnetiserede region er af en første type eller en anden type og derved udtrække værdien af de indkodede databit.

8. Apparat ifølge krav 7, hvor flerheden af magnetsensorelementer er indrettet til simultant af læse en flerhed af første magnetiserede regioner af magnetskalaen (4;10) og analysatoren (7) er indrettet til at bestemme en flerhed af databit der danner et kodeord, idet kodeordet indkoder information omkring den absolutte position af flerheden af magnetsensorelementer i forhold til magnetskalaen (4;10).

9. Apparat ifølge et hvilket som helst af de foregående krav, hvor magnetskalaen er en lineær magnetskala (10) omfattende et lineært array af vekslende første magnetiserede regioner (16) og anden magnetiserede regioner (18).

10. Apparat ifølge et hvilket som helst af kravene 1 til 8, hvor magnetskalaen er en radial magnetskala (4) omfattende en serie af radialt udstrækkende første magnetiserede regioner (16) og anden magnetiserede regioner (18).

11. Apparat ifølge krav 10, hvor flerheden af magnetsensorelementer anvendt til at læse den radiale magnetskala (4) er tilvejebragt som et lineært array og analysatoren (7) påfører en kompensation til sensorsignalerne for at kompensere for den radiale fordeling af de første og anden magnetiserede regioner.

12. Apparat ifølge et hvilket som helst af de foregående krav, hvor pitch'en af det periodisk gentagne magnetmønster af magnetskalaen (4;10) er forskellig fra pitch'en af magnetsensorelementer.

13. Apparat ifølge et hvilket som helst af de foregående krav, hvor flerheden af magnetsensorelementer omfatter et lineært array af Hall-sensorelementer.

14. Apparat ifølge et hvilket som helst af de foregående krav, hvor flerheden af magnetsensorelementer og analysatoren (7) er forsynet med et læsehoved.

DRAWINGS

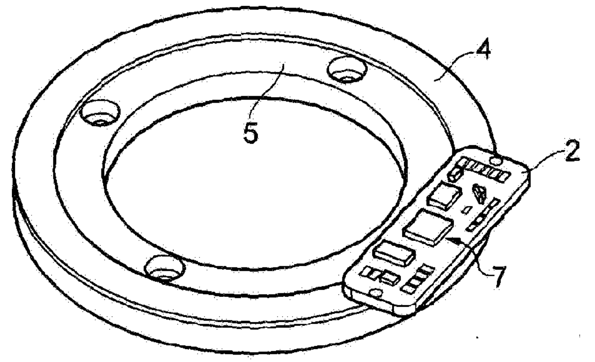


FIG. 1

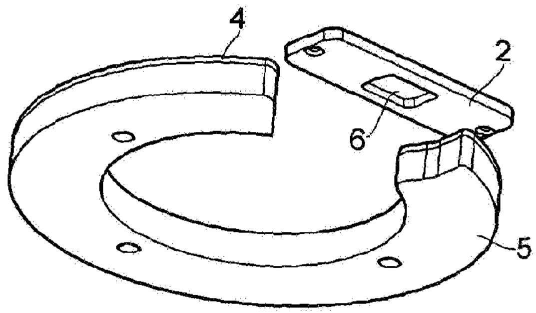


FIG. 2

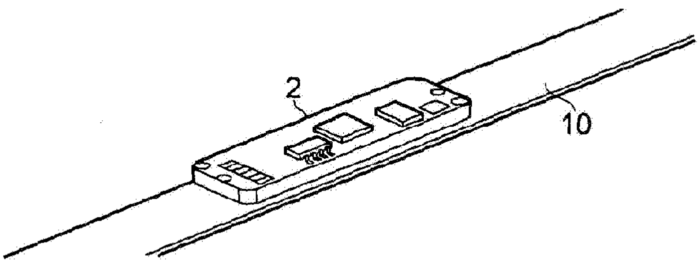


FIG. 3

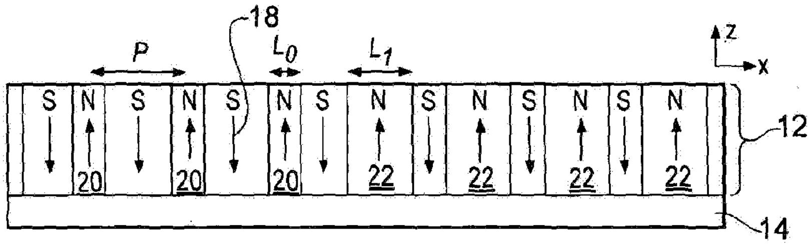


FIG. 4

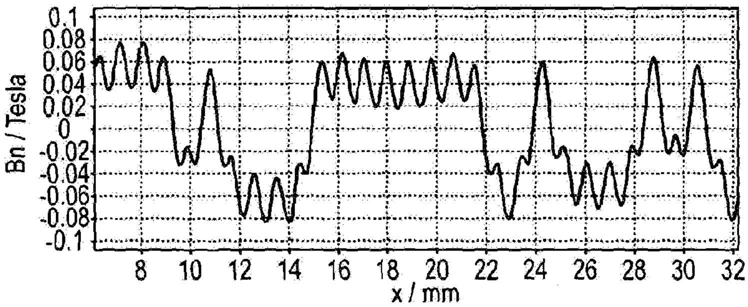
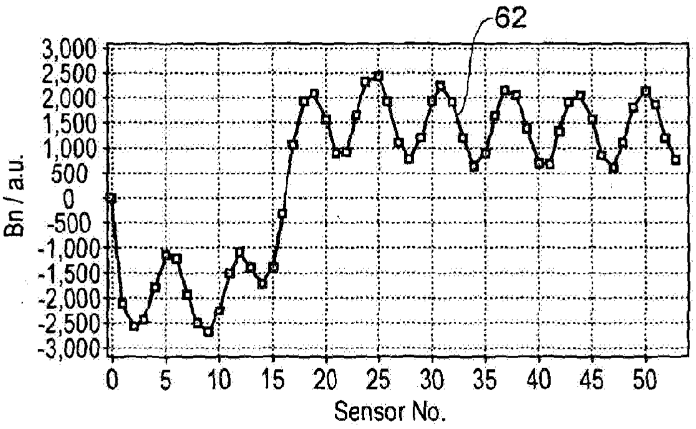


FIG. 5



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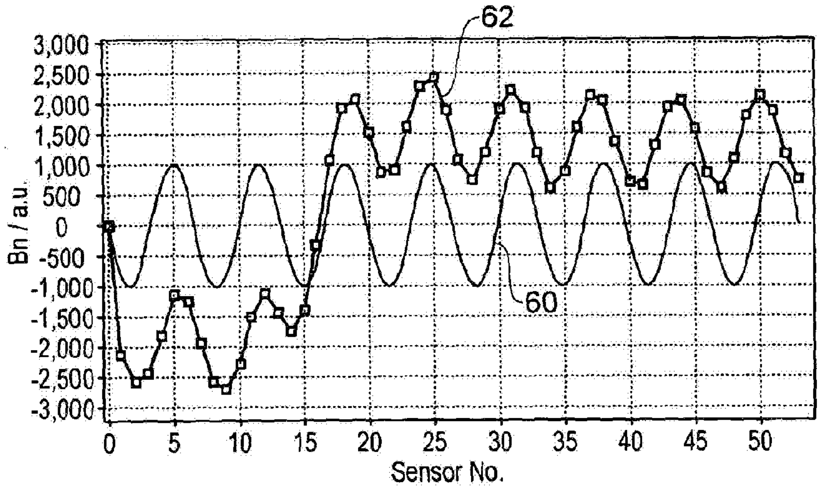
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Bn / a.u.
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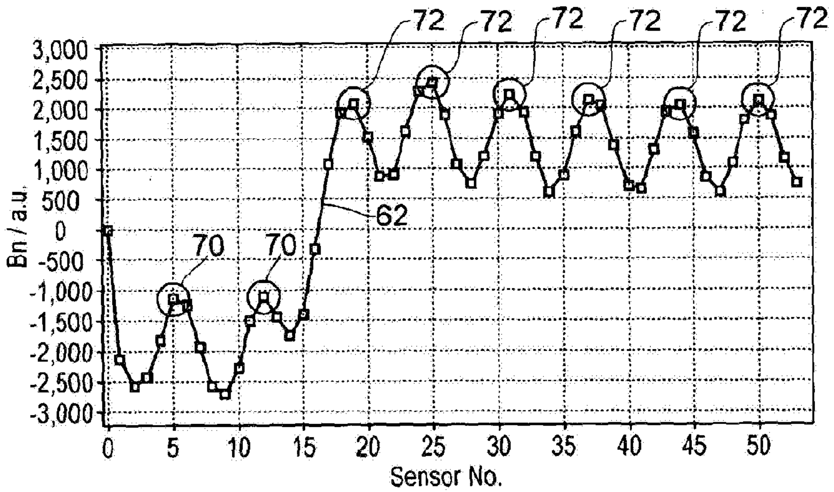
15
20
25
30
35
40
45
50
Sensor No.

FIG. 7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Sensor No.

FIG. 8

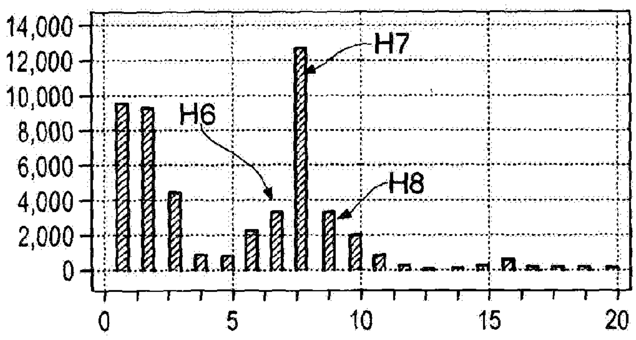

FIG. 9a

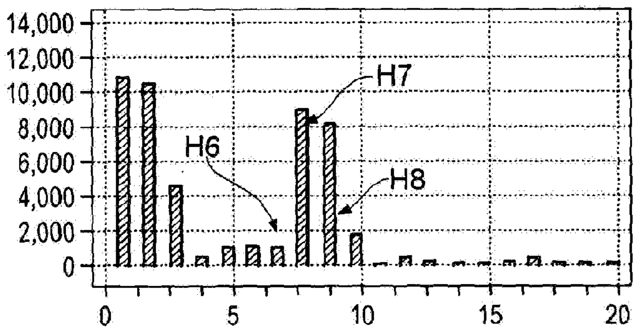

FIG. 9b

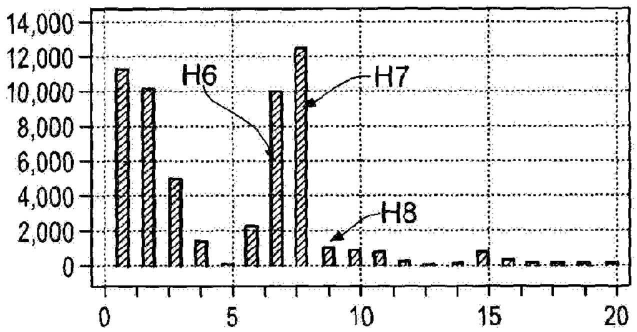

FIG. 9c