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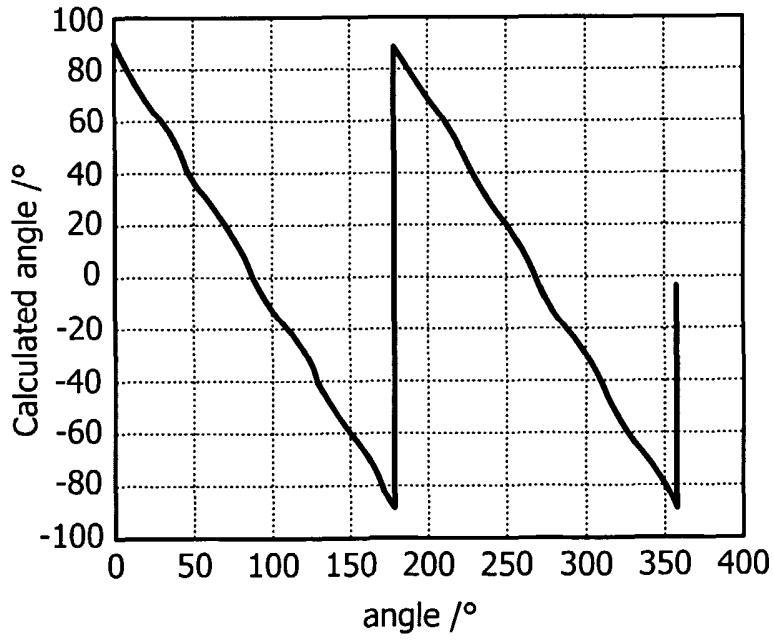
(54) Title: METHOD OF DETERMINING ANGLES



(57) Abstract: In order to provide a method of determining an angle a of an external magnetic field relative to a magnetoresistive angle sensor with two full bridges which respectively supply an output signal $U_1 = U_0\sin(2\alpha)$, $U_2 = U_0\cos(2\alpha)$, wherein the angle determination can be carried out using simple electronic components, it is proposed that the angle α is determined in an analog manner using the relation $\alpha = {}^1/_2 * (U_1/(U_1|+U_2|))-1 * \mathrm{sgn}(U_2)$.

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Published:

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

Method of determining angles

The invention relates to a method of determining an angle α of an external magnetic field relative to a magnetoresistive angle sensor with two full bridges which respectively supply an output signal $U_1 = U_0\sin(2\alpha)$, $U_2 = U_0\cos(2\alpha)$.

Magnetoresistive sensors are usually used to detect angles in motor vehicle technology in order, *inter alia*, to monitor and control the position of a pedal or the position of a throttle. In this case, the magnetoresistive angle sensor usually consists of two full bridges which are offset by 45° with respect to one another, said bridges being exposed to an external magnetic field. The two full bridges supply, as a function of an angle of the external magnetic field relative to a reference axis of the sensor, voltage output signals which can be shown in a manner known to the person skilled in the art using the following relation:

$$U_1 = U_0\sin(2\alpha)$$

$$U_2 = U_0\cos(2\alpha)$$

Here, U_1 and U_2 are the voltage output signals of the two full bridges, U_0 is the voltage amplitude of the output signal, which depends *inter alia* on the ambient temperature, and α is the angle of the external magnetic field relative to a reference axis of the sensor.

The angle α of the external magnetic field relative to the sensor or relative to the magnetoresistive bridges is determined from these output signals, for example using the CORDIC algorithm. In order to implement this algorithm, the analog output signals must be converted into digital signals by means of an analog/digital converter.

The angle α of the external magnetic field relative to the sensor is then determined using the likewise known relation:

$$\alpha = \tfrac{1}{2} * \arctan(U_1/U_2) = \tfrac{1}{2} * \arctan(\sin(2\alpha)/\cos(2\alpha))$$

for example using digital signal processing means suitable for this purpose. Taking account of the sign of the output voltage U_2, the angle α can be calculated with extremely high accuracy using the arctan function over 180°.

A disadvantage of the known sensors and of the signal processing methods used to date is that there is a risk that the signals will become noisy on account of the analog/digital conversion and the signals will be falsified on account of unintentionally occurring offset voltages. These offset voltages may be caused for example by incorrect etching of a resistor of a Wheatstone bridge. Moreover, the conversion into digital pulses requires considerable signal processing time. Furthermore, the digital signal processing means are expensive in terms of initial cost and are liable to faults. For many applications, particularly in motor vehicle technology, the accuracy which can be achieved with such a CORDIC algorithm is much higher than is actually necessary. Likewise, in motor vehicle technology, there is a desire for economic reasons to use sensors that are considerably more cost-effective and do not operate in such a precise manner but which nevertheless have sufficient measurement accuracy.

It is an object of the invention to specify a method of determining an angle using magnetoresistive sensors, which method can be carried out in a simple manner and in which the angle can be reliably determined when determining the angle α of the external magnetic field relative to a sensor. This object is achieved by the features specified in claim 1.

The core concept of the invention is that the arctan function of the above-described CORDIC algorithm can be approximated with sufficient accuracy by the mathematical relation given in claim 1. In this case, the output signals U_i of the two full bridges are subjected to simple mathematical operations such as addition, subtraction, multiplication and division, which require only analog processing of the output signals. It is thus possible, using analog means, to determine with sufficient accuracy the angle α for a wide range of applications. Here, the function $\mathrm{sgn}(U_2)$ is the sign function known per se. This means that the function assumes the value "-1" for an output signal $U_2<0$, the function assumes the value "+1" for an output signal $U_2>0$ and the function assumes the value "0" for the value $U_2=0$.

The advantage of the invention consists in that the method of determining angles can be implemented using simple electronic components known to the person skilled in the art, without it being necessary to carry out analog/digital conversion beforehand. The determination of the angle α is thus accelerated and reliably ensured, and the cost is

considerably reduced since no expensive electronic components that are liable to faults are required for digital signal processing or signal calculation.

Advantageous developments of the invention are characterized in the dependent claims.

By virtue of the use of AMR bridges as specified in claim 2, exact output signals can be obtained as a function of the angle α of the external magnetic field relative to the sensors or bridges. The arrangement of the bridges in the external magnetic fields is known to the person skilled in the art, as is the reading of the corresponding voltage output signals. Advantageously, the bridges may be so-called Wheatstone bridges which are particularly suitable for use in motor vehicle technology with the loads which occur there. The output signals of these bridges can be fed to analog further processing in a simple manner.

In one preferred development, the output signals of the bridges are processed only by means of analog elements or electronic components, as specified in claim 3. This means that the output signals of the bridges are processed only by means of electronic components which implement additions/subtractions, etc., as specified by the relation given in claim 1. Such addition or multiplication elements are known to the person skilled in the art. They offer the advantage that they are cost-effective and are not very liable to faults, so that the determination of the angle α can be carried out in an economic manner with sufficient accuracy using the claimed equation.

It will be understood that the determination of the angle α of an external magnetic field relative to a magnetoresistive sensor may be used in any technical field. Particularly preferably, however, the method is used in motor vehicle technology, as specified in claim 4, in particular to monitor the position of a pedal, for example the gas and/or brake pedal. A position of a throttle for controlling the engine power may also be monitored by means of the method.

The invention will be further described with reference to an example of embodiment shown in the drawings to which, however, the invention is not restricted.

Fig. 1 shows the calculated angle α of an external magnetic field relative to an angle sensor according to the prior art.

Fig. 2 shows the angle α determined according to the invention.

Fig. 3 shows the error in the angle α determined according to the invention.

The graph in Fig. 1 shows the angle α of an external magnetic field relative to a reference axis in a magnetoresistive angle sensor, said angle having been determined for example in accordance with the CORDIC algorithm. In said graph, the calculated angle α is plotted on the y-axis against the angular range from 0 to 360° on the x-axis.

The graph in Fig. 2 shows the angle α obtained in a purely analog manner by means of the method according to the invention, said angle likewise being plotted against the angular range from 0 to 360°. From this graph it can be seen that the calculated angle α fluctuates about the ideal inclined straight lines which are shown in Fig. 1 and result from the digitally exactly calculated arctan function of the CORDIC algorithm. This means that with this method slight deviations from the actual measured value are obtained, although these lie within the tolerances required in particular in motor vehicle technology so that the simplified method that can be carried out using purely analog electronic components meets the requirements.

Fig. 3 shows the difference between the angle determined using the method according to the invention and the actual angle α of the external magnetic field. The angle error, which is shown over a range from 0 to 180°, at no point exceeds the value of +/- 2°. It can furthermore be seen that at the values 0°, 45°, 90°, etc., the angle error is even zero, so that these points can be measured with high accuracy using the new method. In the case of a pedal of a motor vehicle, for example, the angle sensor may be arranged such that when the pedal is not pushed down the angle of the external magnetic field relative to the sensor is 0° and an exact measured value is obtained, and when the pedal is fully pushed down for example 90° is measured.

LIST OF REFERENCES:

α	angle between an external magnetic field and a sensor
U	voltage output signal
U_0	voltage amplitude

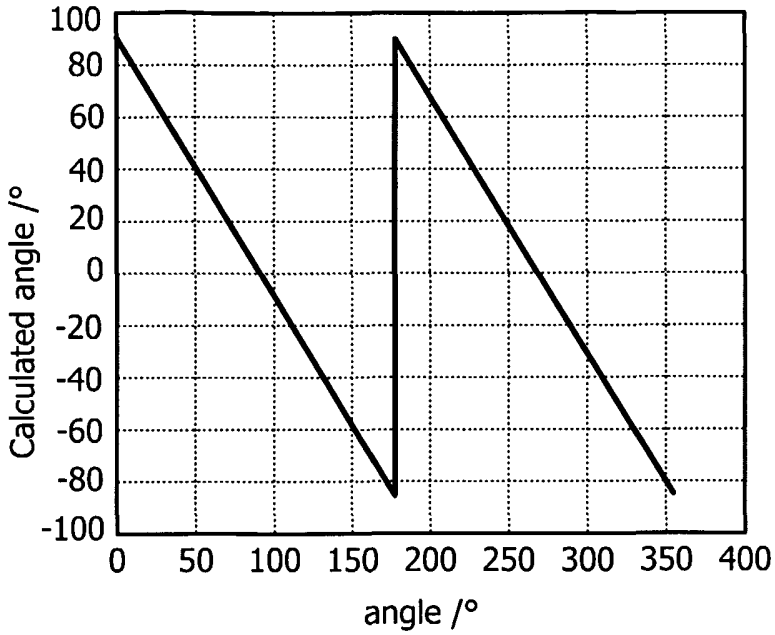
CLAIMS:

1. A method of determining an angle α of an external magnetic field relative to a magnetoresistive angle sensor with two full bridges which respectively supply an output signal $U_1 = U_0\sin(2\alpha)$, $U_2 = U_0\cos(2\alpha)$, characterized in that the angle α is determined in an analog manner using the relation $\alpha = ½ * ((U_1/(|U_1|+|U_2|))-1 * \mathrm{sgn}(U_2)$.

2. A method as claimed in claim 1, characterized in that AMR bridges are used, in particular Wheatstone bridges.

3. A method as claimed in claim 1 or 2, characterized in that output signals of the bridges are processed using analog elements.

4. The use of the method as claimed in any of claims 1 to 3 in motor vehicle technology, in particular for pedal monitoring and/or throttle monitoring.



Prior art

FIG. 1

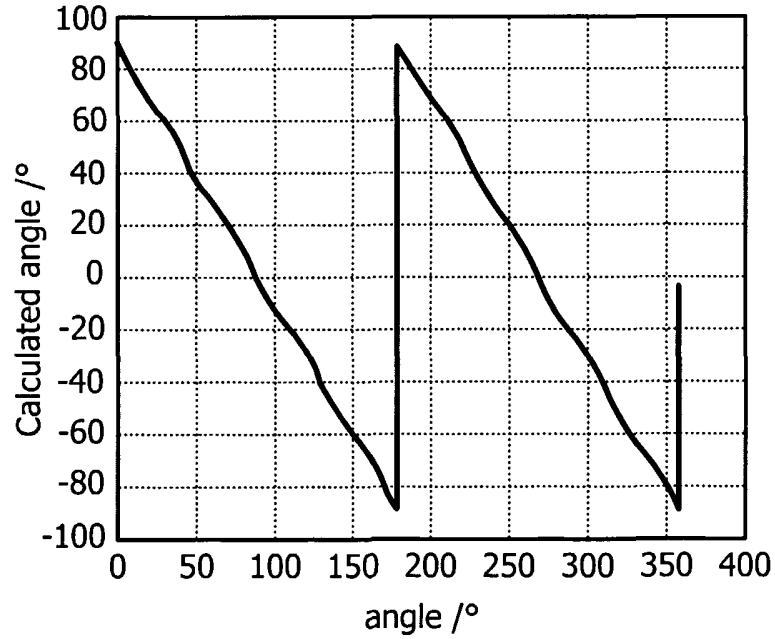


FIG. 2

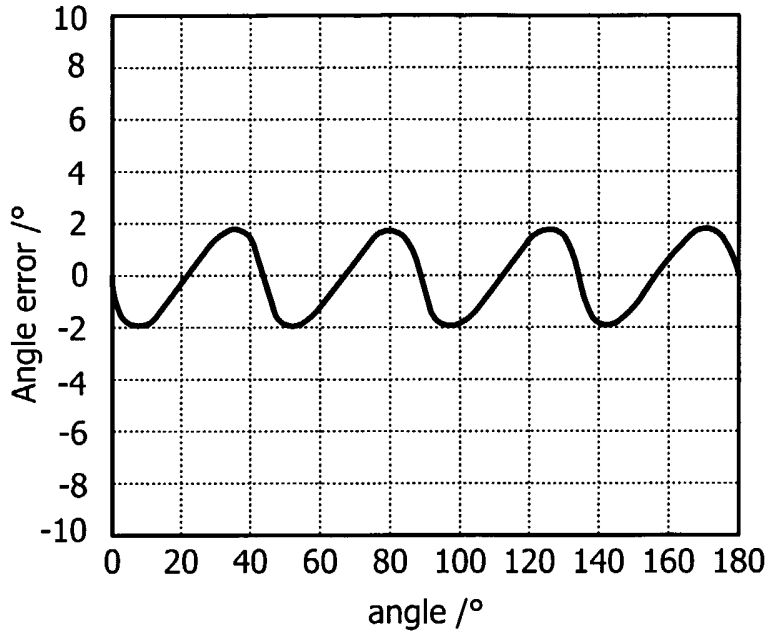

10
8
6
4
2
0
-2
-4
-6
-8
-10
Angle error /°
0
20
40
60
80
100
120
140
160
180
angle /°

FIG. 3

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01R33/02 G01R33/09 G01B7/30

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01R G01D G01B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	DIETMAYER K C J: "Integrated online diagnosis for AMR-based angular measurement systems" SENSORS AND ACTUATORS A, ELSEVIER SEQUOIA S.A., LAUSANNE, CH, vol. 91, no. 1-2, 5 June 2001 (2001-06-05), pages 12-15, XP004239167 ISSN: 0924-4247 the whole document	1-4
A	US 6 501 271 B1 (LENSSEN KARS-MICHIEL H ET AL) 31 December 2002 (2002-12-31) column 2, line 47 - column 4, line 43 figures 1-4	1-4

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 April 2005	13/04/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Modesto, C

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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