(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
25 June 2009 (25.06.2009)

PCT

(10) International Publication Number
WO 2009/078048 A1

(51) International Patent Classification:
G01D 5/14 (2006.01) *F15B 15/28* (2006.01)
G01D 5/244 (2006.01) *F16F 9/32* (2006.01)

(21) International Application Number: PCT/IT2008/000405

(22) International Filing Date: 18 June 2008 (18.06.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
MI2007A002373 19 December 2007 (19.12.2007) IT

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments*

(54) Title: METHOD FOR ESTABLISHING THE DYNAMIC POSITION OF A MECHANICAL TRANSLATION ACTUATOR AND RELATED ENCODER

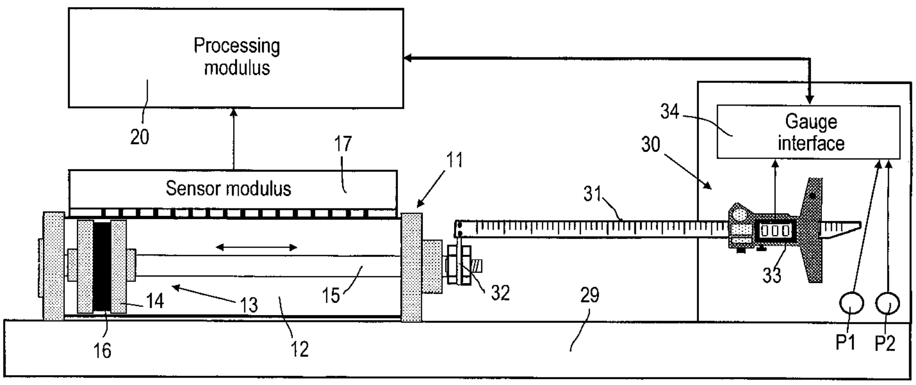

FIG. 9

(57) Abstract: A positional encoder is provided with a plurality of Hall-effect linear sensors aligned along a generating line of a cylinder transparent to a magnetic field; sliding inside the cylinder is a piston the head of which is permanently fixed to a magnetic disk. The piston's shank is connected to a gauge for off line measurement of the absolute position of the magnet and therefore the head of the piston. A multiplexer cyclically acquires samples of responses from all the sensors and sends them on to a processor. The samples are written in a calibrating memory together with the value measured at that position. The operation is repeated for all the positions established by the desired resolution, and the gauge is then disconnected. When operation is in line, the samples passed on by the multiplexer are systematically compared with the calibrated values in each positional map in order to calculate a cumulative distance for each one. The map chosen is the one that provides the minimum cumulative distance and this one gives the estimated positional value. To obtain a better resolution, the single responses between adjacent points can be interpolated.

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Method for establishing the dynamic position of a mechanical translation actuator and related encoder

Field of application

The present invention concerns the field of magnetic positional encoders and, more precisely, a method for establishing the dynamic position of a mechanical actuator for translation purposes, and related encoder.

Review of the known art

In the field of positional encoders, subject of the present invention, a rough distinction may be made between two types of operation, as illustrated in Figures 1 and 2. Figure 1 shows an example in which a first type of encoder is used to establish a position. On looking at the figure it will be seen that an actuator 1 comprises a cylinder 2 inside which a piston 3 translates, said piston consisting of a head 4 joined to a shank 5 that projects from the cylinder for a defined maximum length. A permanently magnetized disk 6 is fixed to the head 4 of the piston 3. The free end of he shank 5 is threaded to receive a tool or some other device requiring translation.. To establish the position of the head 4 of the piston 3, use is made of an encoder 7 comprising N resistances R of equal value and connected in series where each intermediate point in the series is connected to a switch 8 arranged in series to a current generator (not shown). The switch 8 may be of various kinds, for example one using Reed type relays or on/off Hall-effect sensors.

Operatively speaking, when during translation the magnetic disk passes close to one of the switches 8, the magnetic field temporarily switches it on so that voltage V, measured at the ends of the series, will depend on the position of the disk 6, or rather, on the head 4 of the piston 3. The main drawback to this first type of encoder is its lack of precision in establishing the position (about 3 mm for the Reed-type relays and about 2 mm for the Hall on/off sensors). Further, the minimum measurable increase in movement is low in the on/off form since it depends on the number of relays or sensors, per unit of length, that can be placed there, this in turn depending on the bulk of the device.

Figure 2 represents an example of what happens when a second type of encoder is used to establish a position. In relation to the preceding figure, and numbered as before, it will be seen that there is no magnetic disk at the head of the piston 3, and that the encoder, marked number 8, is made differently and is connected to a processing modulus 9. The figure shows that, outside the actuator 1, there is a mechanical connector 10 one end of which is joined to the encoder 8 and the other end to the shank 5 of the piston 3. The encoder can be made in various ways, for example:

a) using a linear potentiometer or an extensometer, the slider being fixed to a mechanical connector 10 so that the voltage measured is proportional to the distance from its origin. This gives excellent precision.
b) suitably placing parallel bands consisting of short dark lengths along the direction of translation of an optic sensor fixed to the mechanical connector 10 and, diversely coded, in binary mode, for the various positions that can be reached;
c) placing a magnetic band along the direction of translation of a head for reading positional encoding registered on the magnetic band.

One drawback to the second type of encoder is that, to establish the position, additional mechanical connectors are required for translating the actuator, a factor which limits its possibilities of use.

The conclusions drawn for the actuators and related positional encoders are repeated in like manner in devices for establishing the level of liquids in receptacles, the same type of encoder being used for these as well.

Summary of the invention

Purpose of the present invention is to overcome the drawbacks described above, its subject being an encoder for establishing the position of a permanent magnet fixed to means sliding within a container transparent to the magnetic field, wherein more than two sensors of magnetic field are placed along the path followed by the translating magnet, each one generating a response signal that varies linearly with the movements of approach and withdrawal of the magnet, said encoder comprising:

- means for cyclic acquisition of samples of all said response signals;
- first means for memorizing maps of calibrated samples of all said response signals at several absolute positions of the magnet;
- second means for storing present samples of all said response signals;
- processing means suitable for minimizing the cumulative distance between said response signals and each of said stored calibration maps;
- data interfacing means controlled by processing means to go out the value of the absolute position stored in the calibration map associated to the minimum distance, as described in claim 1.

Further characteristics of the present invention considered innovative are described in the dependent claims.

According to one aspect of the invention, the sensors of magnetic field are Hall-effect sensors (giving a linear response in the length concerned).

According to another aspect of the invention, the first means of storage include a digital memory previously written by an external processor interfaced with the encoder for receiving the corresponding positional values of the magnet, as measured by the gauge. This confirms that the stored maps univocal correspond to the encoder hosting them, . the maps depending on the responses given by the Hall sensors actually used, allowing for a slight variation between one sensor and another, so forming a sort of "signature" for the encoder.

According to another aspect of the invention, the encoder is interfaced with an external calibrating apparatus that measures and conveys the positional values to said processing means, programmed to produce the calibrating maps and enter them in a digital memory in the first means of storage. Having done this the calibrating apparatus is disconnected.

According to another aspect of the invention, inside the encoder a calibrating apparatus is activated off line to produce and store calibration maps.

According to another aspect of the invention, the sliding means consist of a piston, and the container of a cylinder from which the piston shank projects to function as the actuator of translation; in this case the magnet is discoid. In fluid dynamic and pneumatic applications, the piston and its shank are preferably hermetically sealed inside the cylinder.

According to other aspects of the invention, the Hall sensors are placed at different points along the path of translation; for example, at the same distance one from another, at varying distances, aligned or unaligned. According to the application, sensors are glued to the external, or internal (where the application does not require a hermetic seal), surfaces of the container, maintaining a suitable distance between magnet and sensor, for example a distance of 5 mm.

The number of sensors per unit of length, compatible with the space needed by the device used, may affect maximum precision when estimating the position of the magnet. Space required for commercial devices is not less than 3 mm but that of the devices most often used is slightly less than 5 mm. A space of 10 mm between Hall sensors may be considered acceptable, a distance irrespective of that between the points along the path of translation chosen for purposes of calibration.

A further object of the invention is a method for finding the position of a permanent magnet fixed to sliding means inside a container transparent to the magnetic field, wherein more than two sensors in the magnetic field are placed along the magnet's path of translation, each one generating a response signal variable linearly with the approach and withdrawal movements of the magnet, said method comprising the following steps:

a) cyclic acquisition, out of line, of samples of all response signals obtained at an absolute position of the magnet accurately measured by a gauge, and storage of said samples on a calibration map together with said position;

b) repetition of the preceding step at a number of absolute positions, previously fixed in accordance with the desired degree of accuracy, so obtaining an equivalent number of maps;

c) cyclic acquisition of present samples of all said response signals and their storage;

d) calculation of the cumulative distance between present samples of all said response signals and corresponding samples present in each calibration map;

e) selection of the minimum cumulative distance and index of the associated map where the absolute position of the magnet can be read, as described in an independent claim on method.

The cumulative distance calculated at step (d) is preferably limited to a subset of responses whose distances are the only ones of real significance, typically those of the first four samples in the cycle.

According to one aspect of the method used in the invention, steps from c) to e) are cyclically repeated when the magnet is moving, so obtaining in real time a series of positional details In that case, the first thing to do is define the interval of sampling (cycle of steps c), d), e) allowing the desired degree of positional accuracy to be obtained, and then suit the capacity of calculating the processing means to the number of mathematical operations to be carried out in said interval. The temporal interval of sampling ΔT and the interval of positional sampling ΔS are linked to a speed V of magnet translation according to the following formula: $\Delta T = \Delta S / V$. For example, a speed of 0.1 m/s and ΔS = 1mm gives $\Delta T = 10$ m/s. Clearly, the required capacity of calculation will depend on the number of Hall sensors in use.

According to another aspect of the method used, each calibration map must show interpolation between samples of sensor responses in relation to the adjacent positional values of the magnet using an arbitrary number of interpolation points chosen according to the degree of accuracy required. Use my be made of any known method of interpolation; for example: linear, polynomial, spline, etc: The simplest is linear interpolation and is the one to recommend in this case, in view of the linearity of the sensor responses and will preferably be used in the forthcoming description. The interpolated responses from the sensors associated to corresponding positional values of the magnet, also interpolated, produce a greater concentration of interpolation maps that can help to make the position found more accurate, as in these examples:

- Example 1: assuming that calibration has been carried out at a resolution of 1 mm, and that a factor of 10 has been interpolated among the mapped values, an estimate of the magnet's position is obtained at a resolution of 0.1 mm.
- Example 2: assuming that calibration has been carried out at a resolution of 0.1 mm and that a factor of 10 has been interpolated among the mapped values, an estimate of the piston's position is obtained at a resolution of 0.01 mm, and so on.

As interpolation results in larger calibration maps, when it is intended to trace positional information in real time while the magnet is moving, a check should be made to see if it is worthwhile in view of the extra capacity of calculation needed. For example, with $V = 0.1$ m/s a resolution of 0.1 mm is obtained sampling at $\Delta T = 1$ ms. In that case, for effective resolution the calibration map must be the interpolated map for $\Delta S = 0.1$ mm; in other words it must be ten times larger than the map for $\Delta S = 1$ mm, so as to have a capacity of calculation ten times greater. If using 16 sensors spaced at 10 mm one from another, a processor would be needed with a capacity of calculation of about 10 Mflop which is less than that of the processors used in present-day personal computers.

According to another aspect of the method of the invention, the sampled value of sensor responses stored in the calibration maps becomes altered in accordance with the encoder's working temperature to make up for variations in sensor responses compared with calibrated values. With the rise in working temperature calibrated values are increased of amount contrary to the reduction in sensor responses due to the smaller magnetic field generated by the permanent magnet.

According to an optional aspect of the invention, since the absolute position established for the magnet is based on minimization of an objective function (distance), as described in steps c), d), e), counting on the presence of inevitable, if only small, differences between the various responses, it would be useful to enhance these differences (for calculation purposes only) to avoid any uncertainty on the minimum point that might occur by making rough calculations with whole numbers of limited length.

For this purpose the digitalized samples, of each single response given by the sensors, are first multiplied by a fraction of the value acquired, this value being then added to the initial value. These altered values are used both in calibration and in subsequent comparisons with calibrated values. An example explains the result: let us suppose $V1 = 3$, $V2 = 2.8$, $V3 = 2.5$, and $V4 = 2.4$, the values of four successive samples of the response F1; now, when F1 is aligned with the map, it appears in the module $\Delta 1 = \Delta 2 = \Delta 3 = \Delta 4 = 0$ for all the samples; contrariwise, if F1 is moved from its position on the map, we have module $\Delta 1 = 0.1$; $\Delta 2 = 0.3$; $\Delta 3 = 0.1$ and $\Sigma\Delta = 0.5$: If $Vi' = 1.1\ Vi$ we have: $V1' = 3.9$; $V2' = 3.08$; $V3' = 2.75$ and $V4 = 2.64$, which gives: $\Delta 1' = 0.892$; $\Delta 2' = 0.33$; $\Delta 3 = 0.11$ and $\Sigma\Delta = 1.332 > 0.5$ q.e.d.

Compared with the known art, the advantages of the invention are evident.

- The encoder needs no mechanical parts to support movement of the actuator which in time is subject to wear and non –alignment.
- The invention offers a far greater degree of accuracy than on/off systems due to the resolution in measuring the position of the piston. Interpolation makes it possible to increase this level of accuracy. For example, if sensors are set apart at 10 mm, this gives a resolution of 0.1 mm, but if set at 3 mm, resolution is 0.01 mm.
- The invention can trace the position of the piston when moving at the usual speeds of actuators, an acoustic and/or visual signal being given when approaching the desired position.
- The invention can be used for fluid-dynamic actuators, whether using oil or compressed air, or a mechanical type.
- The invention can serve as a device for establishing the depth of liquids in tanks where access presents difficulties.

<u>Short description of the figures</u>

Further purposes and advantages of the present invention will be made still clearer by the following detailed description of an example of its realization, and by the attached drawings given for explanatory purposes only and in no way limitative, wherein:

- figures 1 and 2 show positional encoders made in accordance with the known art;
- figure 3 shows a positional encoder made according to the present invention;
- figures 4 and 5 illustrate different layouts of sensors used in the encoder in figure 3 along the path of translation followed by a mechanical actuator;
- figure 6 shows a typical response curve of voltage measured at the output of a Hall-effect sensor;
- figure 7 shows the response curves of all the sensors used;
- figure 8 gives a diagram of a modulus for processing signals from sensors used by the encoder in figure 3;

- figure 9 illustrates a calibrating apparatus on the encoder in figure 3;
- figure 10 illustrates the flow diagram for the initial calibration program operated by the processing modulus of the encoder in figure 3, connected to the calibrating apparatus in figure 9;
- figure 11 illustrates the map of two memories, MSENS and MCAL respectively, for the output voltages of sensors read by the processing modulus with corresponding positions of the actuator given by the calibrating device;
- figure 12 briefly explains how the maps of memories MSENS and MICAL would be altered by applying the linear interpolation indicated by the formulae provided;
- figure 13 shows the flow diagram of the program for dynamic measurement of the actuator's position executed by the encoder's processing modulus in figure 3;
- figures 14, 15 and 16 correspond to a table showing digitalized voltage values of the response curves in figure 7.

A detailed description of some preferred forms of realizing the invention.

Illustrated in Figure 3 is an actuator 11 comprising a cylinder 12 made of some non-ferromagnetic material, plastic for example, inside which a piston 13 translates, said piston consisting of a head 14 joined to a shank 15 projecting to some extent from the cylinder 12. A permanently magnetized disk is fixed to the head 14 of the piston 13, for example inside the head 14. The free end of the shank 15 is threaded to receive a tool or some other device requiring translation. In order to establish the position of the head 14 of the piston 13, use is made of an encoder comprising a sensor module 17 equipped with sixteen linear Hall-effect sensors 18 and with a multiplexer 19 connected to a processing modulus 20. The sensors 18 are aligned along a generating line of the cylinder 12 spaced at a constant distance of 10 mm one from another. The figure shows that the 5^{th} sensor S5 is aligned with the magnetic disk 16. This latter can be procured on the market at the required size (for example, one of those marked FLEXO 150-180 in the Magnetic Italiana S.r.l catalogue). The Hall-effect sensors are linear devices, also available on the market, such as those marked MLX90242 in the Microelectronic Integrated Systems' catalogue.

Figure 6 shows the response (Vout x 100) given by the 14^{th} sensor S14 (dotted line) measured along 151 mm between the centre of disk 16 and that of the sensor varying by 1 mm at each step. The curve relates to a magnetic north pole's left-hand approach to the marked face of the sensor; were it otherwise the curve would be reversed in relation to the long horizontal section. Perfect alignment is achieved at the central point of the decline by Vx100 = 250 (2.5 V).

Figure 7 shows the response given by all sixteen sensors 18 in which, for the sake of simplicity, the markers of responses in millimetres, measured for each sensor, are not given. Table 1 (figures 14, 15, 16) shows all the digitalized voltages for the above responses. As appears from the figure, as well as from the tabled values, the curves are not perfectly identical, slightly diverging one from another, and this is always true in actual cases, a factor which the invention cleverly exploits to establish the position of the magnet 16 of the piston 13 as will be explained further on.

Figure 4 shows another possibility of using the sensors 18 where the distance between sensors is not constant but varies according to a pre-arrangement. In this case too, positional establishment works well, without any alteration, showing indifference to tolerances when positioning the sensors. Figure 5 shows yet another possibility of using the sensors 18 arranged in helical form along the surface of the cylinder 12. Circular symmetry of the actuator 11 makes this possible.

Figure 8 illustrates a diagram of blocks in the processing modulus 20 completed by traced outlines of the external components 17 and 19. Modulus 20 includes the following components: a microprocessor 21 with its own bus 22 to which all the other components are interconnected: an analog-to-digital converter 23, a memory 2 for the data read by the sensors; a calibrating memory 25; an interface 26 for input/output data; an interface 27 to external devices (alarms, displays, etc;) and, finally, a

DC feeder 28 that supplies all voltages needed by all the blocks shown. Operation of the processing modulus 20 and, more generally, of the encoder, will be explained in subsequent figures of which Figure 9 shows the calibrating apparatus used only in an initial stage (out of line) while Figures 11 to 13 show the firmware controlling microprocessor 21 and the state of memories 24 and 25. Figure 9 shows a calibrating table to which the actuator 11 and a calibrating apparatus 30 are firmly fixed. This latter is diagrammatically represented by a graded bar mounted on the threaded end of shank 15 so as to translate, together with them, through a display showing the position reached by head 14. The figure shows the initial zero position of the shank 15 entirely inside the cylinder 12, the head 14 against the terminal wall and the magnetic disk 16 opposite the first Hall sensor at a point in the median circle between the two bases of opposing polarities. The display 33 is connected to an interface 34 towards the processing modulus 20. On the gauge 30 are two buttons, P1 and P2, both connected to the interface 34. Button P1 serves to confirm the zero position at the microprocessor while button P2 is an optional if calibration is completely manual. This schematization shown in the figure is not limitative, as any known measuring system can be adopted for calibration purposes so long as it is able to distinguish the smallest positional interval at the required degree of accuracy, for example 0.1 mm. Apart from the initial configuration, all the other measurements can be made automatically through the interface 34 using a calibrating apparatus controllable by means of a computer. The length of the gauge can vary as the situation requires; experiments using pistons up to 500 mm long have been made with the encoder.

When in operation and with reference to Figure 10, calibration begins at stage C0 with the piston 13 and gauge 30 positioned at zero. The end of stage C0 is decided by the operator on pressing button P1. In C1 an index k is zeroed, said index k allowing for the forward movement of the piston 13 (automatic, or manual with button P2) for previously established lengths according to the resolution required. Index k assumes M= 153 values (from 0 to M-1). In C2 the positional reading made by gauge 30 is transferred to the processor 21. In C3 an index i is zeroed, its purpose being to direct the individual sensors. Index I assumes N = 16 values (from 0 to N-1). At this point the initial writing address in calibrating memory 25, indicated by MCAL, is established at stage C4. The program enters a cycle of stages C5, C6, C7, C8 and C9 in which a sample VS(i) of the response from each sensor is repeatedly acquired and written, in sequence, in memory 24, indicated by MSENS and, similarly, the position POS (k), measured by gauge 30 for that cycle, and passed by its own interface 34 to the processor's interface 26, is written in memory MCAL. When the present cycle has been completed, the positional index k is increased by one unit to stage C10, the preceding cycle is repeated, and so on, with repetition of M calibrating cycles, the last of which appears at stage C11. The next stage, C12, tests for the presence of interpolation: if this is not required, it terminates at C13; otherwise interpolation proceeds at C14.

Figure 11 shows the content of memories MSENS and MCAL on completion of calibration. Each memory is written in sequence starting from the address given by the combination of indices i, k = 0.0.

Figure 12 again shows the content of memory MSENS as in the preceding figure, but only to the first two values of the k index to show how linear interpolation actually works. Interpolation is made between samples VS(i,k+1) and VS(i,k) in order to generate F-1 new samples in each interval, the interpolation factor being F which, in the example given, is F = 10. The same applies to positional values and therefore to the content of memory MCAL. The calibrating memories with interpolated data are called MSENS-int and MCAL-int and these replace MSENS and MCAL. The interpolated VS samples are expressed as VSI(j,k) and the interpolated POS positions of the piston are expressed as POSI(j,k) in which the j index varies between 0 and F-1. This having been established, the interpolated values are determined by the following expressions:

$$VSI(j,k)=VS(i,k)+\frac{j\cdot\Delta(i,k)}{F};\quad (j=0,\ldots,F-1)\quad ,$$

wherein $\Delta(i,k)=\left|VS(i,k+1)-VS(i,k)\right|$

$$POSI(j,k)=POS(k)+\frac{j\cdot POS(k)}{F};\quad (j=0,\ldots,F-1)\quad .$$

The figure shows images of memories MSENS-int and MCAL-int for interval $\Delta(0.0)$

Figure 13 shows the flow diagram of the program that controls the encoder, when the piston 13 moves forward (automatic or manual movement with button P2), to trace their positions as it reaches them. In order to simplify the flow chart, no indication is given of the optional steps that could be taken to signal, acoustically and/or visually, a previously set position at which the piston could stop, but the explanation already given would enable any expert to handle this feature. The cyclic stage of establishing a position begins at step R0 with acquisition of N samples of the responses from all sensors, indicated by VSW(i) to distinguish them from the VS(i) samples present in the MSENS calibrating memory (or from the VSI(i) samples in the MSENS-int memory if interpolation has been made). Subsequent steps are ideally divisible in the following two parts:

• *Calculation of all objective OBJ functions at the M=153 positions of piston 13 previously calibrated* (steps R1 to R5) *and*

• *Search for the minimum of OBJ(k)* steps R6 to R11)

repeated on establishing each new position (signalled) at step R11.

The first part begins at step R1 indicating the field of variability of index k and the k-nth objective OBJ(k) function. R2 gives the field of variability of index i indicating the acquired VSW(i) samples compared with the calibrated VS(i) samples. Index I covers its entire field at increase in index k. In R3 a calibrated VS(i) sample is read by memory MSENS and passed into records under the same name. In R4 the following partial objective function is calculated for the VSW(i) sample: *OBJ(i)* =

$|VSW(i) - VS(i)|$ that corresponds to the "distance" between compared samples: The OBJ(i) function is not limitative and other functions, suitable for the purpose, can be used, for example $OBJ(i)=(VSW(i) - VS(i))$, or $OBJ(i) =(VSW(i)-VS(i))^2$, or others still that are not explicitly linked to the difference between values. In the same way all suitable objective functions can be considered for establishing a "distance" between compared values. At the next step R5, the OBJ(i) value is added to the preceding ones to obtain a cumulative function of $OBJ(k)=\sum_{i=0}^{N-1} OBJ(i)$ representing the k-nth position.

From the first part, the second continues on to step R6 wherein an initial value of a MIN variable is set indicating the increasingly lower value of the OBJ(k) functions during minimization. The initial MIN value is the maximum in order to be certain of the result in subsequent comparisons. R7 indicates variability of the k index. In R8 a comparison is made between OBJ(k) and the variable MIN value, this comparison being repeated by increasing k till a value of OBJ(k) < MIN is reached. In that case, in step R9, the MIN variable assumes a value of OBJ(k) and, at step R10, the k value is stored as mink and comparison is resumed until completed. Finally, at step R11, the POS(mink) element w ill indicate the absolute minimum of objective function OBJ(k) corresponding to the absolute position of the piston 13. This position will appear on the display (not shown) o be transferred to the operator by interface 26, after which, with the piston moving, another cycle will begin to establish the piston's position.

Based on the description given for a preferred example of the invention, some changes can clearly be made by an expert in the field without thereby departing from its sphere, as will be seen from the following claims.

CLAIMS

1. Encoder for establishing the position of a permanent magnet (16) fixed to sliding means (14, 15) within a container (12) transparent to the magnetic field, in which more than two sensors (18) of said magnetic field are placed along the path of translation of the magnet (16) to provide information on its position, wherein the following are included:
- means for cyclic acquisition (19) of samples of the response signals given by said sensors (18), each sensor generating a linearly variable response signal when approaching and leaving the magnet (16);
- first means (25) for storing calibrating maps (MSENS, MCAL) of samples of all said response signals (VS) at a plurality of absolute positions of the magnet (16);
- second means (24) for storing present samples of all said response signals;
- processing means (20) so formed to minimize the cumulative distance between said present response signals (VSW) and each of said stored calibrating maps (MSENS, MCAL);
- interfacing means (26) controlled by the processing means (20) to go out the value of absolute position (POS(minK)) stored in the calibrating map (MCAL) associated to the minimum distance.
2. Encoder as in claim 1, wherein said sensors (18) of the magnetic field are linear Hall-effect sensors.
3. Encoder as in claim 1 or 2, wherein the first storage means (25) include a digital memory (MSENS, MCAL) previously written by an external processor interfaced with the encoder to receive present samples (VS) of said response signals, and with an external calibrating apparatus (30) for receiving the corresponding positional values (POS) of the magnet (16) measured by said apparatus (30).
4. Encoder as in claim 1 or 2, wherein it is interfaced with an external calibrating apparatus (30) that measures and passes the positional values (POS) of the magnet (16) to said processing means (20) which

are programmed to obtain said calibrating maps (MSENS, MCAL) and to write them in a digital memory (25) in said first storage means.

5. Encoder as in claim 1 or 2, where in it includes a calibrating apparatus activated off line to obtain and store said calibrating maps (MSENS, MCAL).

6. Encoder as in any one of claims from 1 to 5, wherein said sliding means consist of a piston (13) and said container consists of a cylinder (12) from which the shank (15) of the piston projects to function as actuator of translation, the magnet (16) being discoidal.

7. Encoder as in claim 6, wherein the piston and its shank are hermetically sealed inside the cylinder (12) for fluid-dynamic or pneumatic applications.

8. Encoder as in claim 2, wherein the Hall-effect sensors are aligned at a constant distance one from another along the path of translation followed by the magnet (16).

9. Encoder as in claim 2, wherein the Hall-effect sensors lie at a variable distance one from another along the path of translation followed by the magnet (16).

10. Encoder as in claim 2, wherein the Hall-effect sensors lie in unaligned positions along the path of translation followed by the magnet (16).

11. Method for establishing the position of a permanent magnet (16) fixed to sliding means (14, 15) within a container (12) transparent to the magnetic field in which more than two sensors (18) in the magnetic field lie along the path of translation followed by the magnet (16) in order to supply information on its position, wherein the following steps are included:

   a) placing sensors (18) in the magnetic field, having a response signal linearly variable with approach and withdrawal of the magnet (16);

   b) cyclic acquisition out of line of samples (VS) of said response signals obtained at an absolute position (POS) of the magnet (16) measured by a gauge (30) and storage of said samples

(VS) in a calibrating map (MSENS, MCAL) together with the above position (POS);

c) repetition of the preceding step at a number of absolute positions previously established according to the degree of accuracy required, so obtaining the same number of maps;

d) cyclic acquisition of present samples (VSW) of all said response signals and their storage;

e) calculation of the cumulative distance between present samples of said response signals (VSW) and corresponding samples (VS) present in each calibrating map (MSENS);

f) selection of the minimum (MIN) cumulative distance and index (minK) thereto associated (MCAL) and reading the absolute position (POS(mink)) on the map of magnet (16).

12. Method as in claim 11, wherein the cumulative distance calculated at step (e) is limited to a subset of said responses whose distances are the only ones of significance, typically those that supply the first four samples in the cycle.

13. Method as in claim 11 or 12, wherein i steps (d), (e), (f) are cyclically repeated while the magnet (16) is moving, so obtaining in real time a sequence of items of positional information (VSW, POS).

14. Method as in one of the claims from 11 to 13, wherein an interpolation is made on each calibrating map (MSENS, MCAL) among samples (VS) of responses from the sensors (18) relating to positional values adjacent to the magnet (16), using a number of interpolation points chosen at random according to the degree of accuracy required.

15. Method as in claim 14, where in said interpolation is linear.

16. Method as in one of the claims from 11 to 15, wherein the values (VS) of responses from the sensors (18) stored in the calibrating maps (MSENS) increase with a rise in working temperature of the encoder to compensate for the reduced values (VS) of responses from the sensors (18).

17. Method as in one of the claims from 11 to 16, wherein before any further operation , the samples (VS, VSW) of each single response from the sensors (18) are multiplied by a fraction of the acquired value, and the one so obtained is added to the initial value.
18. Method as in claim 11, wherein said cumulative distance calculated at step (e) is equal to the sum of single distances calculated for all the sensors (18) in relation to an absolute position of the magnet (16).
19. Method as in claim 18, wherein each single distance is given by the module of differences among the compared values (VSW, VS).
20. Method as in claim 18, wherein each single distance is given by the square of the module of differences among the compared values (VSW, VS).

KNOWN ART

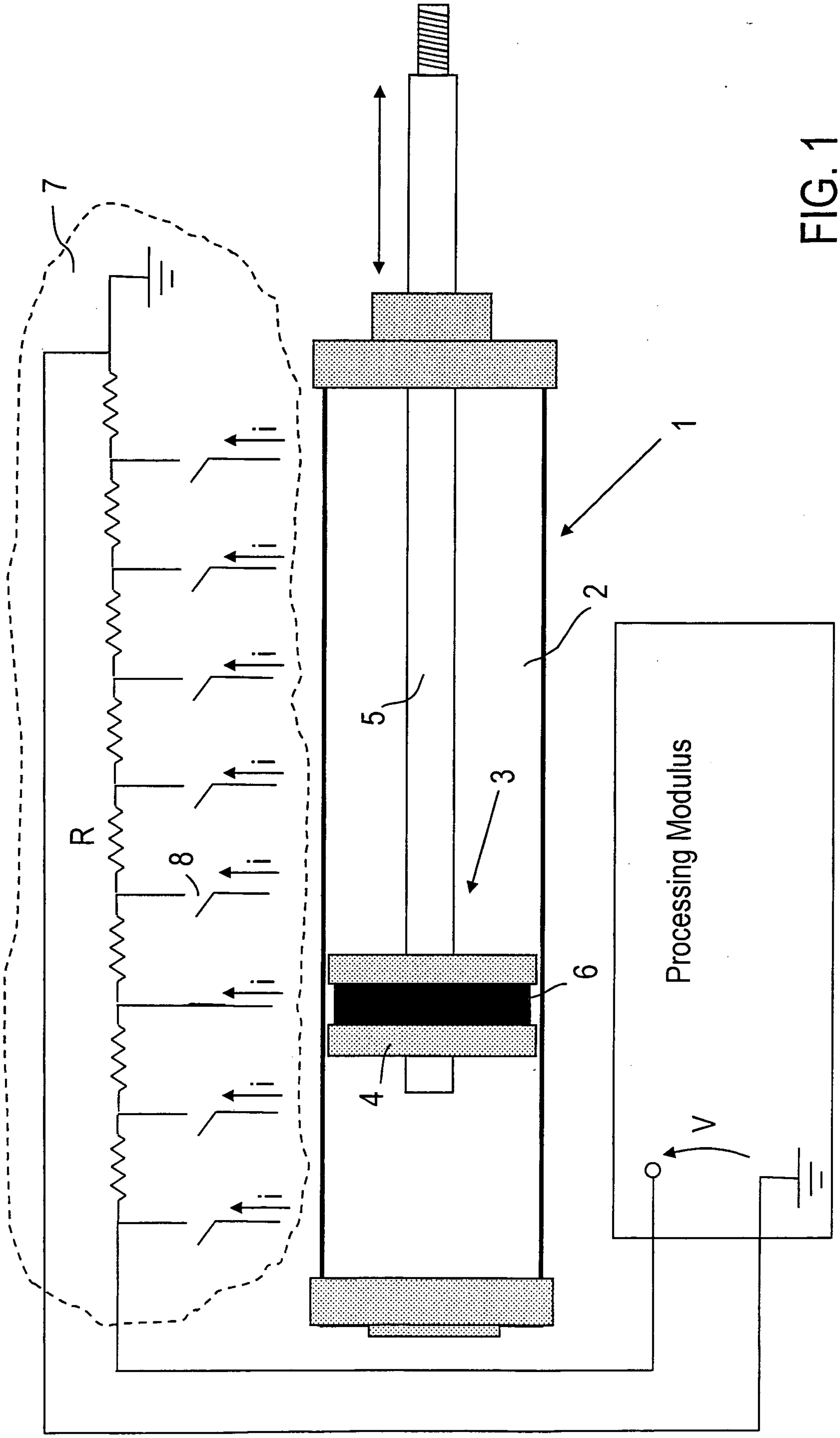


FIG. 1

KNOWN ART

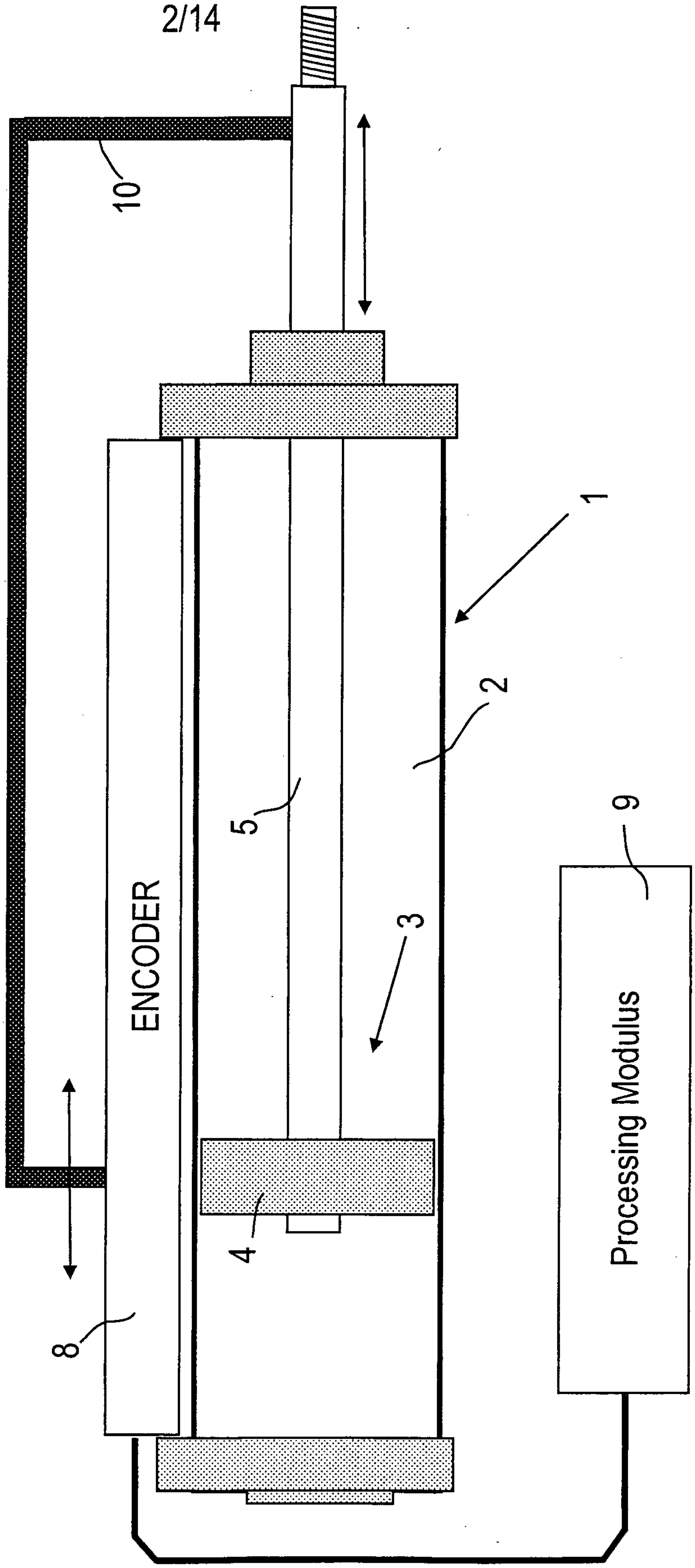


FIG. 2

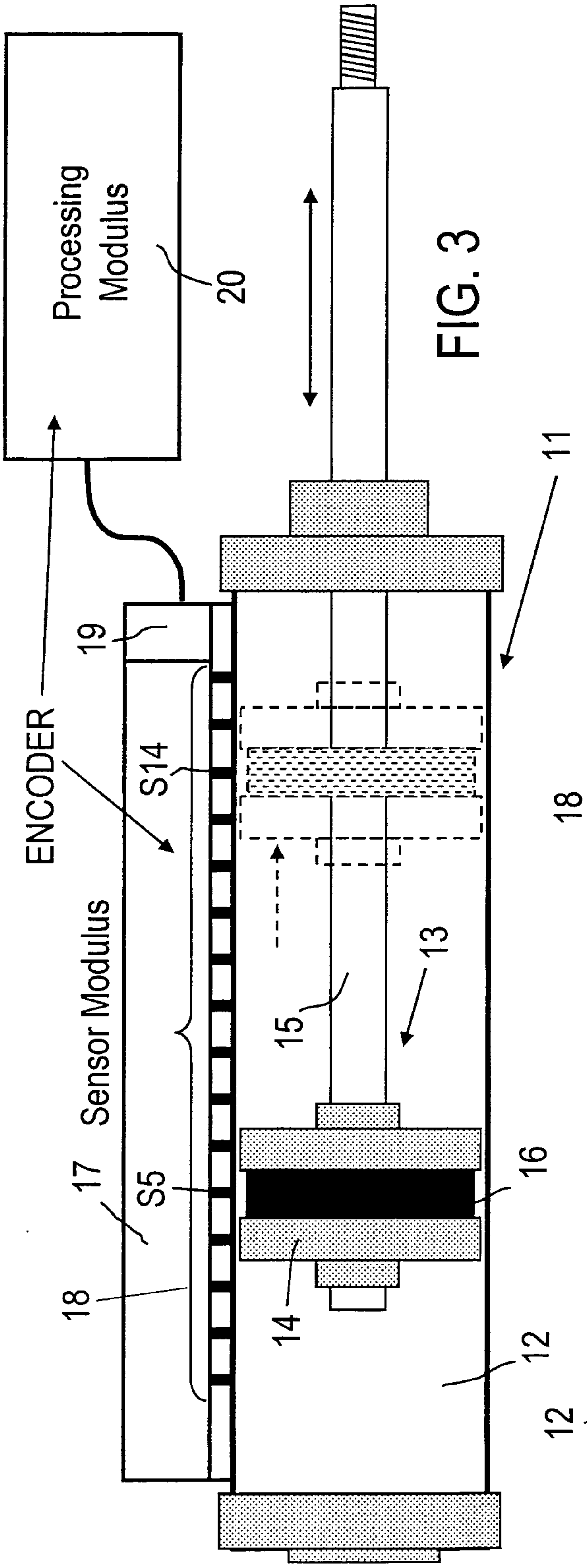


FIG. 3

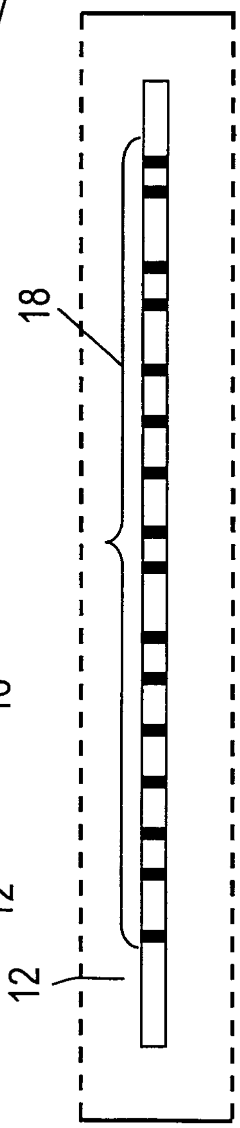


FIG. 4

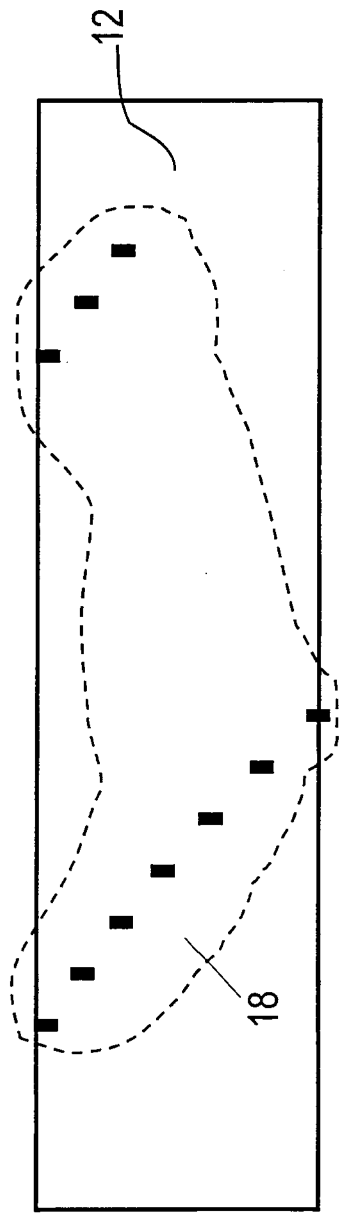


FIG. 5

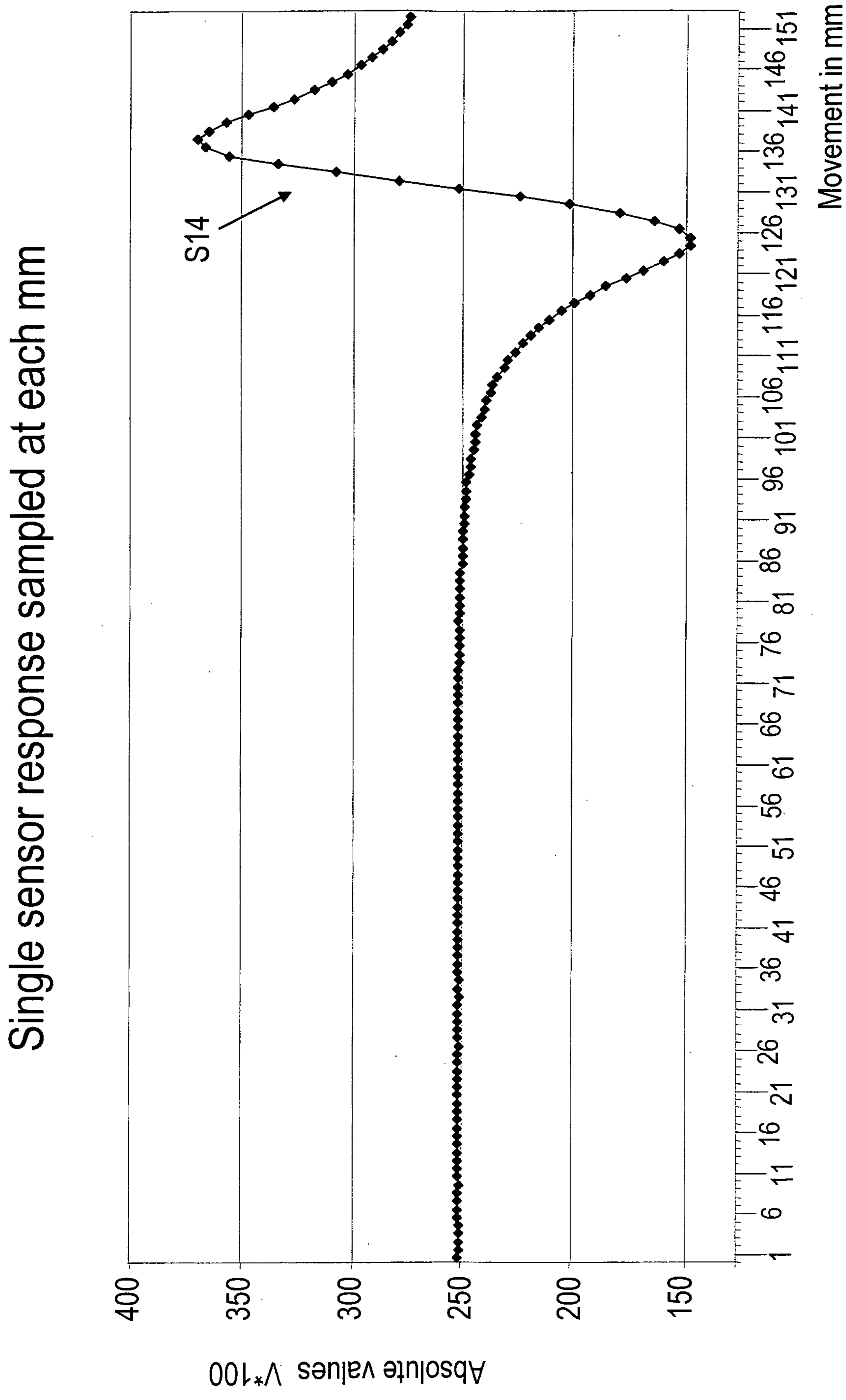

Single sensor response sampled at each mm
S14
Absolute values V*100
400
350
300
250
200
150
1 6 11 16 21 26 31 36 41 46 51 56 61 66 71 76 81 86 91 96 101 106 111 116 121 126 131 136 141 146 151
Movement in mm

FIG. 6

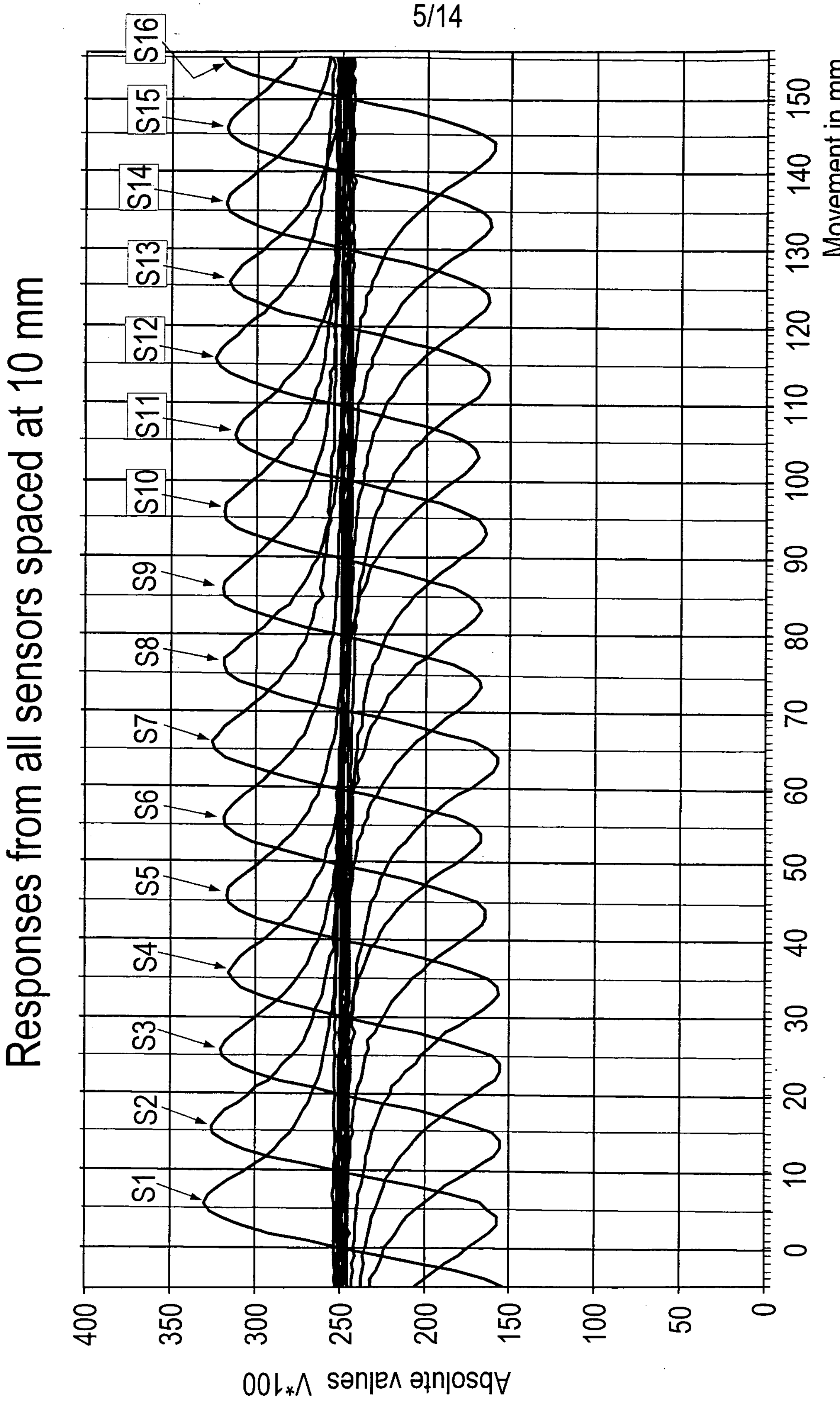

Responses from all sensors spaced at 10 mm
S1
S2
S3
S4
S5
S6
S7
S8
S9
S10
S11
S12
S13
S14
S15
S16
Absolute values V*100
400
350
300
250
200
150
100
50
0
Movement in mm
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

FIG. 7

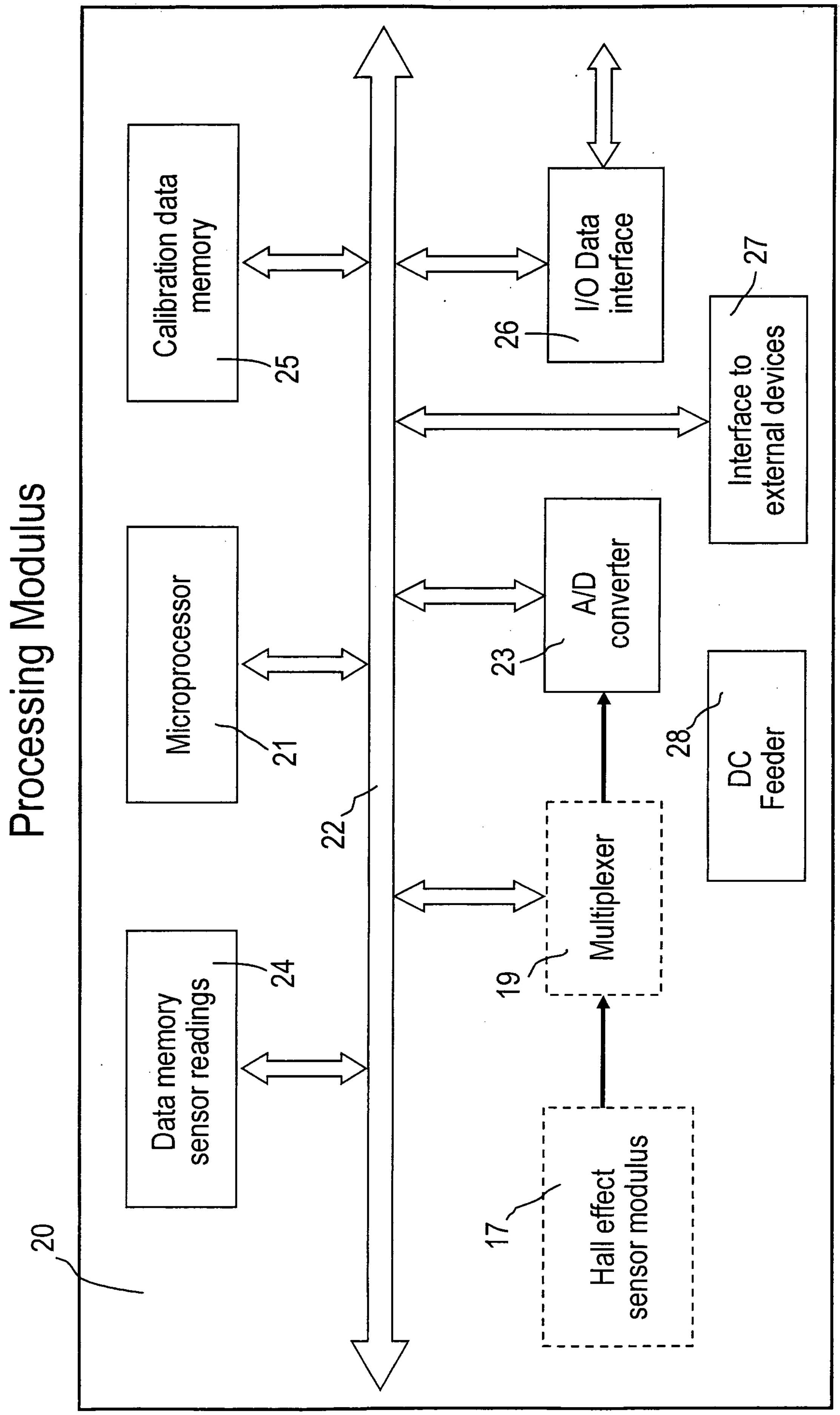

Processing Modulus
20
Calibration data memory
25
Microprocessor
21
Data memory sensor readings
24
22
I/O Data interface
26
Interface to external devices
27
A/D converter
23
DC Feeder
28
Multiplexer
19
Hall effect sensor modulus
17

FIG. 8

ENCODER CALIBRATING APPARATUS

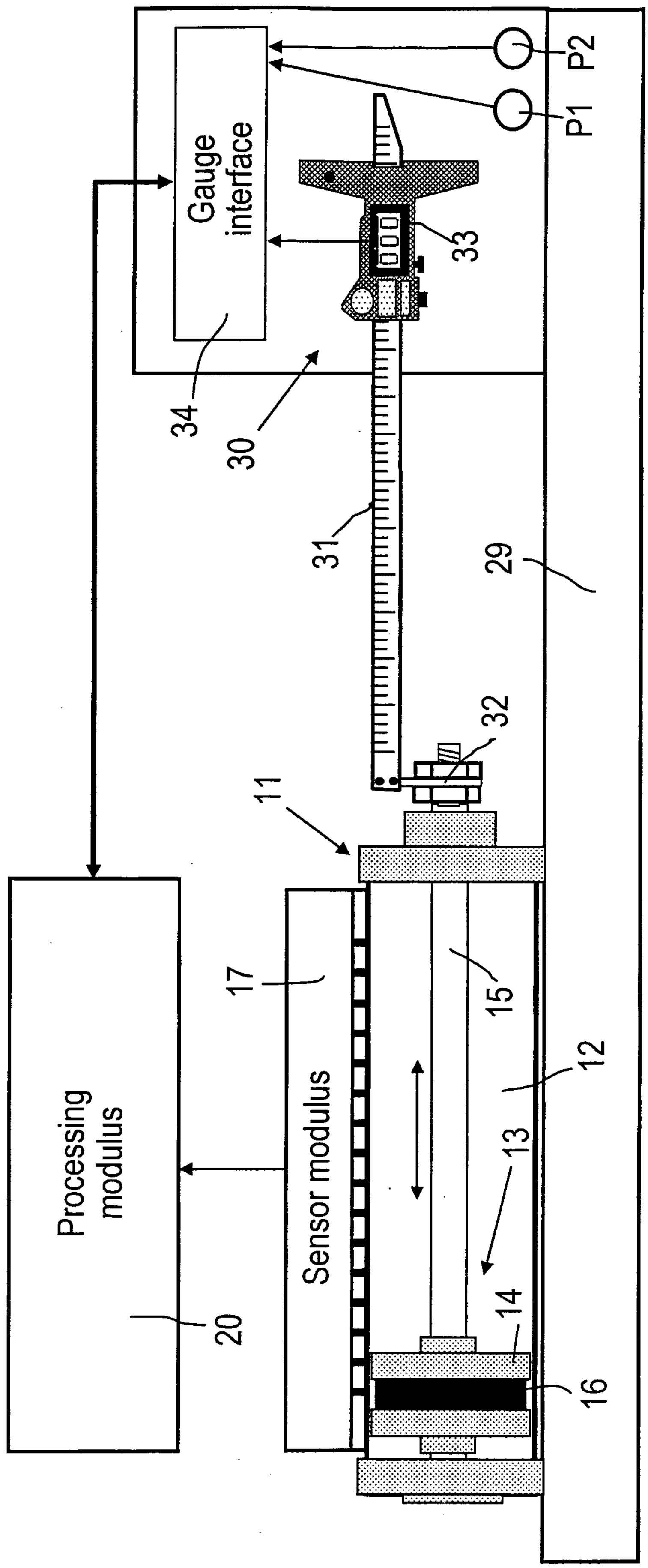


FIG. 9

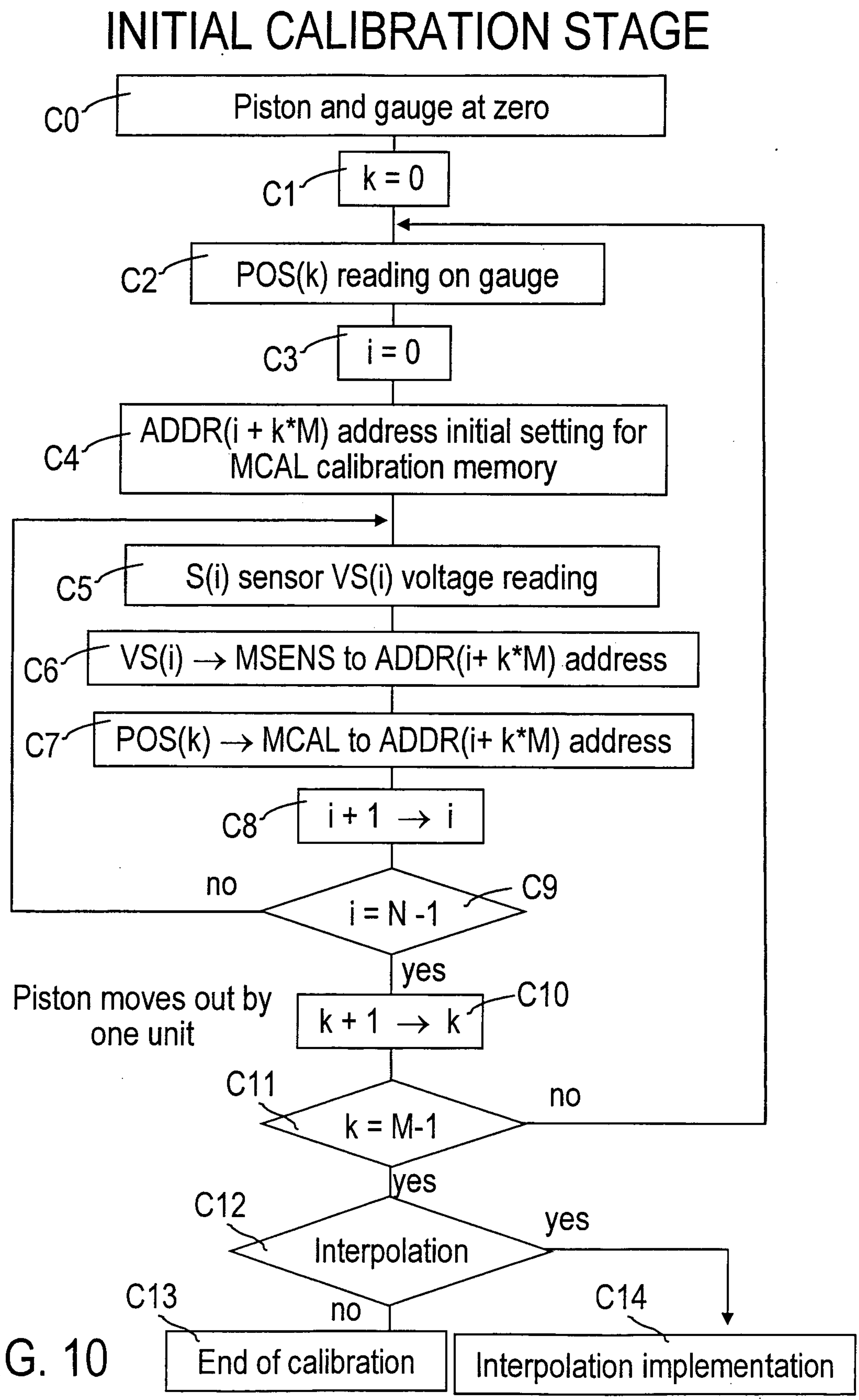

INITIAL CALIBRATION STAGE
C0
Piston and gauge at zero
C1
k = 0
C2
POS(k) reading on gauge
C3
i = 0
C4
ADDR(i + k*M) address initial setting for MCAL calibration memory
C5
S(i) sensor VS(i) voltage reading
C6
VS(i) → MSENS to ADDR(i+ k*M) address
C7
POS(k) → MCAL to ADDR(i+ k*M) address
C8
i + 1 → i
no
C9
i = N -1
yes
Piston moves out by one unit
C10
k + 1 → k
C11
k = M-1
no
yes
C12
Interpolation
yes
no
C13
End of calibration
C14
Interpolation implementation

FIG. 10

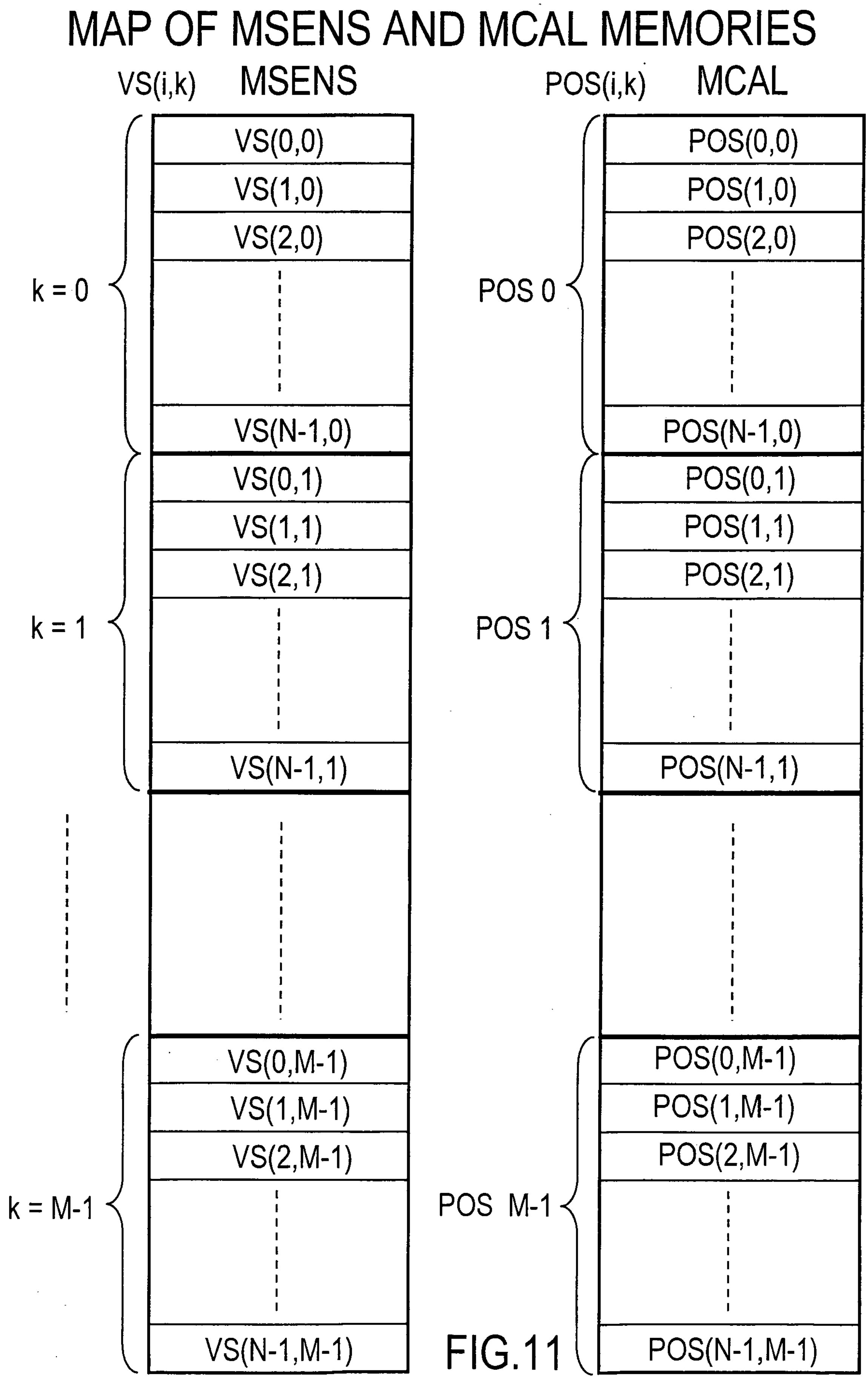

MAP OF MSENS AND MCAL MEMORIES
VS(i,k)
MSENS
POS(i,k)
MCAL
VS(0,0)
VS(1,0)
VS(2,0)
VS(N-1,0)
k = 0
VS(0,1)
VS(1,1)
VS(2,1)
VS(N-1,1)
k = 1
VS(0,M-1)
VS(1,M-1)
VS(2,M-1)
VS(N-1,M-1)
k = M-1
POS(0,0)
POS(1,0)
POS(2,0)
POS(N-1,0)
POS 0
POS(0,1)
POS(1,1)
POS(2,1)
POS(N-1,1)
POS 1
POS(0,M-1)
POS(1,M-1)
POS(2,M-1)
POS(N-1,M-1)
POS M-1

FIG.11

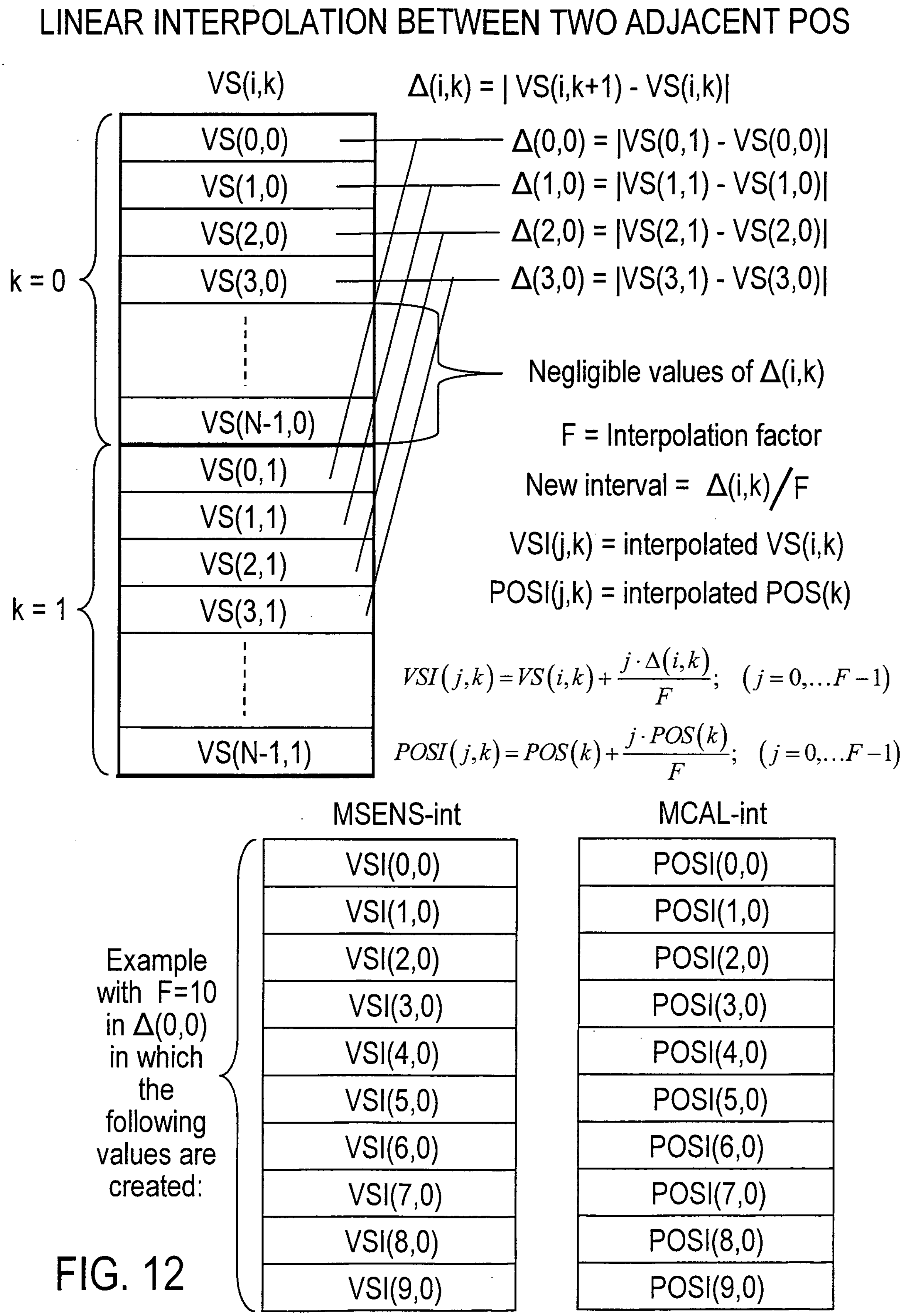
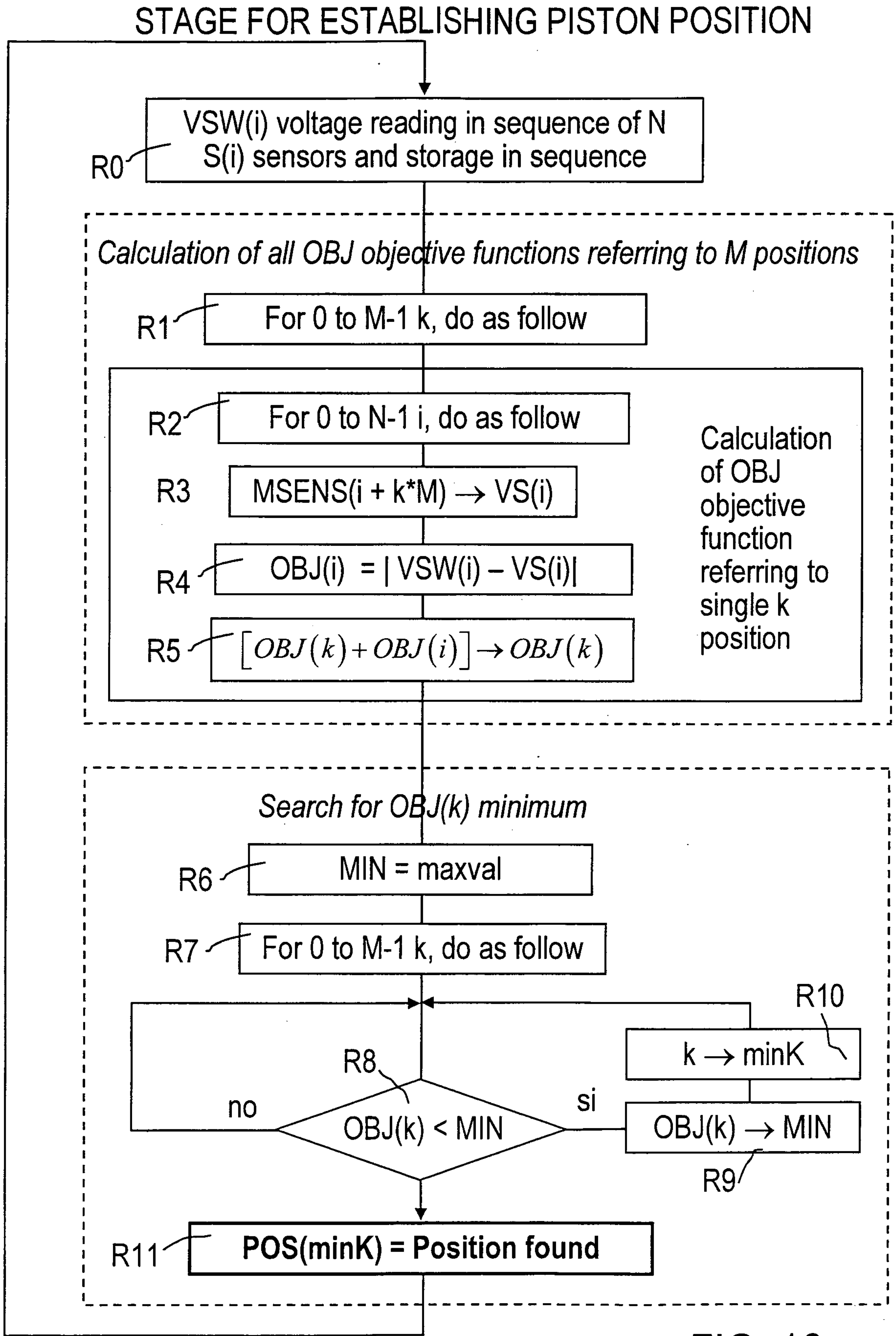

LINEAR INTERPOLATION BETWEEN TWO ADJACENT POS
VS(i,k)
Δ(i,k) = | VS(i,k+1) - VS(i,k)|
k = 0
VS(0,0)
VS(1,0)
VS(2,0)
VS(3,0)
VS(N-1,0)
Δ(0,0) = |VS(0,1) - VS(0,0)|
Δ(1,0) = |VS(1,1) - VS(1,0)|
Δ(2,0) = |VS(2,1) - VS(2,0)|
Δ(3,0) = |VS(3,1) - VS(3,0)|
Negligible values of Δ(i,k)
F = Interpolation factor
New interval = Δ(i,k)/F
k = 1
VS(0,1)
VS(1,1)
VS(2,1)
VS(3,1)
VS(N-1,1)
VSI(j,k) = interpolated VS(i,k)
POSI(j,k) = interpolated POS(k)
VSI(j,k) = VS(i,k) + j·Δ(i,k)/F; (j = 0,...F-1)
POSI(j,k) = POS(k) + j·POS(k)/F; (j = 0,...F-1)
MSENS-int
MCAL-int
Example with F=10 in Δ(0,0) in which the following values are created:
VSI(0,0)
VSI(1,0)
VSI(2,0)
VSI(3,0)
VSI(4,0)
VSI(5,0)
VSI(6,0)
VSI(7,0)
VSI(8,0)
VSI(9,0)
POSI(0,0)
POSI(1,0)
POSI(2,0)
POSI(3,0)
POSI(4,0)
POSI(5,0)
POSI(6,0)
POSI(7,0)
POSI(8,0)
POSI(9,0)

FIG. 12



STAGE FOR ESTABLISHING PISTON POSITION
VSW(i) voltage reading in sequence of N S(i) sensors and storage in sequence
R0
Calculation of all OBJ objective functions referring to M positions
R1
For 0 to M-1 k, do as follow
R2
For 0 to N-1 i, do as follow
R3
MSENS(i + k*M) → VS(i)
R4
OBJ(i) = | VSW(i) – VS(i)|
R5
[OBJ(k) + OBJ(i)] → OBJ(k)
Calculation of OBJ objective function referring to single k position
Search for OBJ(k) minimum
R6
MIN = maxval
R7
For 0 to M-1 k, do as follow
R8
OBJ(k) < MIN
no
si
R10
k → minK
OBJ(k) → MIN
R9
R11
POS(minK) = Position found

FIG. 13

TABLE 1

TABULATEDVALUES OF HALL-EFFECT SENSOR RESPONSES SEEN IN FIGURE 7

(8 bits; 1V = 000; 4V = 255)

mm	S1	S2	S3	S4	S5	S6	S7	S3	S8	S9	S10	S11	S12	S13	S14	S15	S16
-1	101	53	103	115	122	128	134	126	131	131	125	134	124	126	127	128	128
0	126	45	100	114	122	128	133	126	131	131	125	134	124	125	127	128	128
1	154	37	97	113	121	128	134	126	131	131	125	134	124	125	127	128	128
2	181	30	94	112	121	128	133	126	131	131	125	134	124	125	127	128	128
3	204	26	89	111	121	127	133	126	131	131	125	134	124	125	127	128	128
4	224	26	85	110	120	127	133	126	131	131	125	134	124	126	127	128	128
5	235	32	80	108	119	127	133	126	131	131	125	134	124	126	127	128	128
6	239	43	74	106	119	127	133	126	131	131	125	134	124	126	127	128	128
7	236	59	67	104	118	127	133	126	131	131	125	134	124	126	127	128	128
8	230	78	60	102	117	127	133	125	131	131	125	134	124	125	127	128	128
9	222	100	53	100	117	126	133	125	131	131	125	134	124	126	127	128	128
10	212	127	44	97	116	126	133	126	131	131	125	134	124	126	127	128	128
11	203	153	36	94	115	126	133	126	131	131	125	134	124	126	127	128	128
12	194	180	30	90	114	125	133	125	131	131	125	134	124	126	127	128	128
13	187	204	25	86	113	125	133	125	131	131	125	134	124	126	127	128	128
14	180	222	25	81	112	124	133	126	131	131	125	134	124	126	127	128	128
15	174	234	30	76	110	124	132	125	131	131	125	134	124	126	127	128	128
16	169	239	40	70	108	123	132	125	131	131	125	134	125	126	127	128	128
17	164	236	56	63	106	123	132	125	131	131	125	134	124	126	127	128	128
18	160	229	76	56	104	122	132	125	131	131	125	134	124	126	127	128	128
19	157	220	99	48	101	121	132	125	131	131	125	134	124	126	127	128	128
20	153	211	124	40	99	120	131	125	131	131	125	134	124	126	127	128	128
21	151	202	151	32	95	120	131	125	131	131	125	134	124	126	127	128	128
22	148	193	177	26	92	118	131	125	131	131	125	134	125	126	127	128	128
23	146	186	202	22	87	117	130	125	131	131	125	134	124	126	127	128	128
24	144	179	221	21	83	116	130	125	131	131	125	134	124	126	127	128	128
25	143	173	232	26	78	114	129	124	131	131	125	134	124	125	127	128	128
26	141	168	236	36	71	113	129	124	130	131	125	134	124	126	127	128	128
27	140	163	233	53	65	111	128	125	131	131	125	133	124	126	127	128	128
28	139	159	226	74	57	108	127	124	130	131	125	134	124	126	127	128	128
29	138	156	216	97	50	106	126	124	130	131	125	134	124	126	127	128	128
30	137	153	207	122	41	103	125	123	130	131	125	134	124	126	127	128	128
31	136	150	198	148	34	100	125	123	130	131	125	134	124	125	127	128	128
32	135	148	190	174	27	97	124	122	130	131	125	134	124	126	127	128	128
33	135	145	182	198	23	92	122	122	130	131	125	134	124	125	127	128	128
34	134	143	176	216	22	88	121	122	130	131	125	134	124	126	127	128	128
35	134	142	170	227	27	82	119	121	130	131	125	134	124	126	127	128	128
36	133	141	165	230	38	76	118	121	129	131	125	134	124	126	127	128	128
37	133	139	161	228	54	70	116	120	129	130	125	134	124	126	127	128	128
38	132	138	157	221	74	63	114	119	129	131	125	134	124	126	127	128	128
39	132	137	153	212	97	55	111	118	129	130	125	134	124	126	127	128	128
40	132	136	150	203	122	47	108	117	129	130	125	134	124	126	127	128	128
41	131	135	147	194	149	40	105	117	128	130	125	134	124	126	127	128	128
42	131	134	145	186	175	34	102	115	127	130	125	134	124	126	127	128	128
43	131	134	143	179	200	30	97	114	127	130	125	134	125	126	127	128	128
44	131	133	141	172	218	30	93	113	127	130	125	134	124	126	127	128	128
45	131	133	140	167	230	34	88	111	126	130	125	134	124	126	127	128	128
46	130	132	138	162	234	45	82	109	126	129	125	134	125	126	127	128	128
47	130	132	137	157	231	61	75	107	125	129	124	134	124	126	127	128	128

FIG. 14

48	130	131	136	153	224	82	68	105	124	129	125	134	124	126	127	128	128
49	130	131	135	150	216	104	61	103	123	129	125	134	124	126	127	128	128
50	130	131	134	147	207	129	53	100	123	128	124	134	124	126	127	128	128
51	130	130	133	144	198	154	45	96	122	128	124	134	124	126	127	128	128
52	130	130	132	142	190	180	38	92	121	128	124	134	124	126	127	128	128
53	129	130	132	140	182	204	34	88	119	127	124	134	124	126	127	128	128
54	129	130	131	138	176	222	33	83	118	127	124	133	124	126	127	128	128
55	129	129	131	136	170	233	37	78	116	126	124	133	125	126	127	128	128
56	129	129	130	135	164	237	47	72	115	126	124	133	124	126	127	128	128
57	129	129	130	133	160	234	63	65	113	125	123	133	124	126	127	128	128
58	129	129	129	132	156	227	82	57	110	125	123	133	124	126	127	128	128
59	129	129	129	131	152	219	105	49	108	124	123	133	124	126	127	128	128
60	129	129	129	130	149	210	130	41	105	123	123	133	124	126	127	128	128
61	129	129	128	130	146	201	156	33	102	122	122	133	124	126	127	128	128
62	129	128	128	129	144	192	184	25	98	121	122	133	124	126	127	128	128
63	129	129	128	128	141	185	208	20	94	119	122	133	124	126	127	128	128
64	129	128	128	128	140	179	227	20	89	118	121	132	124	126	127	128	128
65	129	128	127	127	138	173	239	24	84	117	120	132	124	126	127	128	128
66	129	128	127	127	137	168	244	35	78	115	121	132	124	126	127	128	128
67	129	128	127	126	136	163	241	51	72	113	119	132	124	126	127	128	128
68	129	128	127	126	134	159	235	72	65	111	119	132	124	126	127	128	128
69	129	128	127	126	133	156	226	95	57	108	118	131	124	126	127	128	128
70	129	128	127	125	132	153	217	120	49	106	117	131	124	126	127	128	128
71	129	128	127	125	132	150	208	149	41	102	116	131	124	126	127	128	128
72	129	128	127	125	131	148	199	176	35	99	115	130	124	125	127	128	128
73	129	128	127	125	130	146	192	202	31	94	114	130	123	125	127	128	128
74	129	128	126	124	130	144	185	222	31	90	113	129	123	125	127	128	128
75	128	128	126	124	129	142	179	234	36	85	111	129	123	125	127	128	128
76	129	128	126	124	129	141	174	239	46	79	109	128	123	125	127	128	128
77	128	128	126	124	128	140	169	237	63	72	108	128	123	126	127	128	128
78	129	128	126	124	128	138	165	230	83	65	106	127	122	125	127	128	128
79	129	128	126	124	127	138	162	222	105	57	103	126	122	125	127	128	128
80	129	128	126	123	127	136	158	211	132	49	100	125	122	125	127	128	128
81	129	128	126	123	127	136	156	203	157	42	98	124	122	125	127	128	128
82	129	128	126	123	127	135	153	194	184	35	94	123	121	125	127	128	128
83	129	128	126	123	126	134	151	185	209	31	90	122	121	125	127	128	128
84	128	128	126	123	126	134	149	179	226	30	85	121	120	124	127	128	128
85	128	128	126	123	126	133	148	173	236	35	80	119	120	124	127	128	128
86	129	128	126	123	126	133	146	167	240	46	74	117	119	124	127	129	129
87	128	127	126	123	126	132	145	163	237	62	68	115	119	124	126	128	128
88	128	127	126	123	126	132	144	158	230	82	61	113	118	124	126	128	128
89	128	128	126	123	126	132	143	155	222	105	53	110	117	123	126	128	128
90	128	127	126	123	126	131	141	152	212	130	46	108	116	123	126	128	128
91	128	128	126	123	125	131	141	149	204	156	38	104	115	123	126	128	128
92	128	128	126	123	125	131	140	146	195	182	31	100	114	122	126	128	128
93	129	128	126	123	125	131	140	144	188	206	27	96	113	122	126	128	128
94	128	127	126	123	125	130	139	142	181	225	26	92	112	122	126	128	128
95	129	127	126	122	125	130	138	140	175	236	30	86	110	121	126	128	128
96	128	128	126	123	125	130	138	139	170	240	40	80	108	120	126	128	128
97	128	127	126	122	125	130	138	138	166	237	55	74	106	120	125	128	128
98	128	128	126	122	125	130	137	136	162	230	75	66	104	119	125	128	128
99	128	128	126	122	125	130	137	135	158	222	97	59	102	118	125	128	128
100	128	128	126	122	125	130	137	134	155	213	121	51	99	118	124	127	128
101	128	128	126	122	125	130	136	134	153	203	148	43	96	117	124	127	128
102	128	127	126	122	124	130	136	133	150	195	173	36	92	115	124	127	128
103	128	127	126	122	124	129	136	132	148	188	197	32	88	114	124	127	128

FIG. 15

104	128	127	126	122	124	129	136	131	146	181	216	32	83	113	123	127	128
105	128	127	126	122	124	129	136	131	145	175	228	37	78	111	122	127	128
106	129	127	126	122	124	129	135	130	143	170	232	48	72	110	122	126	128
107	128	128	126	122	125	129	135	130	142	166	229	64	66	108	122	126	128
108	128	127	126	122	124	129	135	130	141	162	223	84	59	105	121	126	128
109	128	127	126	122	125	129	135	129	140	158	214	108	51	103	120	126	128
110	128	127	126	122	124	129	135	129	139	155	206	133	43	100	119	126	128
111	128	127	126	122	124	129	135	129	138	153	197	160	35	96	118	125	128
112	128	128	126	122	124	129	135	128	137	150	189	186	28	93	117	125	128
113	128	127	126	122	125	129	134	128	137	148	182	212	24	89	116	124	128
114	128	127	126	122	124	129	134	128	136	146	175	231	23	84	115	124	128
115	128	127	125	122	124	129	134	128	136	145	169	243	28	79	113	123	128
116	128	127	126	122	124	129	134	127	135	144	164	247	39	73	111	123	128
117	128	127	126	122	124	129	134	127	135	142	160	245	55	66	109	122	128
118	128	127	126	122	124	129	134	127	134	141	156	237	76	59	107	122	128
119	128	127	125	122	124	129	134	127	134	140	152	228	99	50	104	121	128
120	128	127	126	122	124	129	134	127	134	139	149	218	125	42	102	120	128
121	129	127	126	122	124	129	134	127	134	138	146	209	152	33	99	119	128
122	128	127	126	122	124	129	134	127	133	137	144	201	179	26	95	118	128
123	128	127	126	122	124	129	134	127	133	137	141	193	206	21	91	116	128
124	128	127	126	122	124	129	134	127	133	136	140	186	225	21	86	115	128
125	128	127	126	122	124	129	134	127	133	136	139	180	236	26	80	113	128
126	128	127	125	122	124	129	134	126	133	135	137	174	239	37	74	111	128
127	128	127	126	122	124	129	134	126	132	135	136	170	235	53	67	109	128
128	128	127	126	122	124	129	134	126	132	134	135	165	227	75	59	107	128
129	128	127	126	122	124	129	134	126	132	134	134	162	217	98	51	105	128
130	128	127	126	122	124	128	134	126	132	134	133	159	207	126	42	101	128
131	128	128	126	122	124	128	134	126	132	133	132	156	198	153	33	98	128
132	128	127	126	122	124	128	134	126	132	133	131	153	190	182	25	94	128
133	128	127	126	122	124	129	134	126	132	133	131	151	182	208	20	90	128
134	128	127	126	122	124	129	134	126	132	133	130	150	175	230	18	84	128
135	128	127	126	122	124	128	134	126	132	133	130	148	169	240	22	79	128
136	128	128	126	122	124	128	134	126	132	133	129	146	163	244	33	72	128
137	128	128	126	122	124	128	134	126	132	132	129	145	159	239	50	65	128
138	128	127	126	122	124	128	134	126	131	132	128	144	155	231	72	57	128
139	128	127	125	122	124	128	134	126	132	132	128	143	151	221	97	47	128
140	128	128	126	122	124	128	134	126	131	132	128	142	148	210	124	38	128
141	128	127	125	122	124	128	134	126	131	132	128	141	146	201	152	29	128
142	128	127	126	122	124	128	134	126	132	132	127	140	143	192	182	21	128
143	128	127	126	122	124	128	134	126	131	132	127	140	141	184	209	16	128
144	128	128	125	122	124	128	134	126	131	132	127	139	139	177	229	15	128
145	128	128	126	122	124	128	134	126	131	132	127	139	138	171	241	21	128
146	128	127	126	122	124	129	134	126	131	132	127	138	137	166	244	32	128
147	128	127	126	122	124	128	134	126	131	132	126	138	135	161	240	51	128
148	128	127	126	122	124	128	134	126	131	131	126	137	134	157	232	74	128
149	128	127	125	122	124	128	134	126	131	131	127	137	133	153	222	100	128
150	128	128	125	122	124	128	134	126	131	131	126	137	132	150	212	128	128
151	128	128	125	122	124	128	134	126	131	131	126	136	131	148	202	159	128

FIG. 16

INTERNATIONAL SEARCH REPORT

International application No
PCT/IT2008/000405

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01D5/14 G01D5/244 F15B15/28 F16F9/32

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)
G01D F15B F16F

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 589 769 A (KRAHN DONALD R [US]) 31 December 1996 (1996-12-31) columns 2-3; figures 2-4 -----	1,2
X	US 4 652 821 A (KREFT HANS-DIETRICH [DE]) 24 March 1987 (1987-03-24) columns 1,3; figures 1,2 -----	1
A	US 6 580 269 B2 (HILIGSMANN VINCENT [BE] ET AL) 17 June 2003 (2003-06-17) columns 1-3; figure 1 -----	1,2

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

[X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
2 March 2009	11/05/2009

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, Fax: (+31-70) 340-3016	Kallinger, Christian

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IT2008/000405

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers allsearchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search reportcovers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

see annex

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-2

   Directed to the choice of the magnetic sensors in order to provide a linear response of the sensor signal.

   ---

2. claims: 3-5, 11-13

   Directed to the generation of calibration data via an external calibration apparatus.

   ---

3. claims: 6-7

   Directed to the application of the position sensor in a fluid-dynamic or pneumatic piston.

   ---

4. claims: 8-10

   Directed to a favourable geometry of the position sensor by defining the positioning of the individual sensors.

   ---

5. claims: 14-15

   Directed to the improvement of the resolution by interpolation.

   ---

6. claim: 16

   Directed to the improvement of the reliability via temperature compensation.

   ---

7. claims: 7,17-20

   Directed to the improvement of the position detection via improving the comparison of measured values and stored data.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IT2008/000405

Patent document cited in search report		Publication date	Patent family member(s)			Publication date
US 5589769	A	31-12-1996	DE	69510357	D1	22-07-1999
			DE	69510357	T2	30-12-1999
			EP	0783666	A1	16-07-1997
			WO	9610731	A1	11-04-1996
US 4652821	A	24-03-1987	DE	3244891	A1	07-06-1984
			FR	2537268	A1	08-06-1984
			GB	2131554	A	20-06-1984
			JP	1721532	C	24-12-1992
			JP	4007442	B	12-02-1992
			JP	59141003	A	13-08-1984
US 6580269	B2	17-06-2003	US	2002008513	A1	24-01-2002