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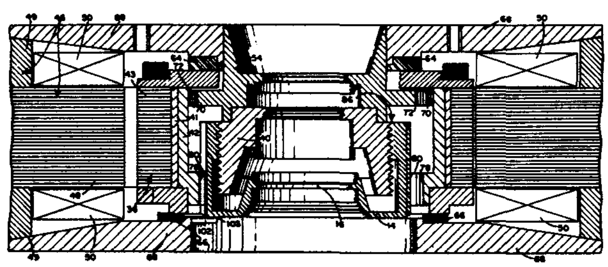
(54) Electromagnetically actuated lens drive.

(57) This invention relates to a motorised focusing system with an electromagnetically actuated lens drive, for example for use in a photographic camera having an automatic rangefinder. The lens (16) is adjusted axially by the rotation of the lens holder (14) on a fixed support (40). The lens holder is rotated by an epicyclic motor having a stator (46) concentric with the optical axis of the lens with poles (48) which are energised sequentially to cause a hollow armature (36) within the stator to roll eccentrically around a fixed armature support (54). Armature teeth (70) engage teeth (72) on the fixed armature support and armature teeth (78) engage teeth (80) on the lens holder (14), resulting in a speed reduction in the drive to the lens holder. The lens moves incrementally in response to pulses applied to the stator windings, a given number of pulses representing a known amount of axial movement of the lens.



EP 0 000 982 A1

ELECTROMAGNETICALLY ACTUATED LENS DRIVE

This invention relates generally to focusing apparatus for moving a lens element along its optical axis; it can be advantageously applied to a camera having automated apparatus for moving a camera lens element to focus an image at the film plane.

Automatic lens focusing systems have been discussed and disclosed in the literature for several years. In these systems a rotating motor, controlled by an electrical signal, is mechanically coupled to move a lens element parallel to its axis to focus an image at the film plane of the camera. In prior systems, a continuous feedback interaction is provided to generate for the electronic circuits within the camera an electrical signal representing either the present position of the lens in its path of movement or the quality of the present focus of the image at the film plane. In this manner, further movement of the lens, including the direction of movement, is controlled by the electrical circuits.

Even though often discussed in the literature, automatic focusing systems have not been entirely successful in still or movie cameras. Part of the reason may be that the feedback interaction undesirably introduces an added degree of complexity in the camera system. In addition, even though the electronics packages used in current camera equipment generally take advantage of recent technological innovations to reduce their physical size, similar technological advances have not been adapted to reduce the size of motor drives for automatic focusing mechanisms. The motor drives noted in the art have used a continuously movable motor, typically an analog-driven D.C. motor, which is mechanically coupled as by a worm drive to move the lens element to the focus position. The mechanical and electrical constraints heretofore placed on this kind of motor operation have retarded its miniaturization.

Needless to say, stepping motors -- which are typically larger in size and weight than continously movable analog motors and which are well known in non-camera applications where their size and bulk are acceptable -- have not generally been used for focusing in photographic cameras. This is so even though they could be driven by digital circuitry. Stepping motors have apparently not generally been used because the increment of rotational movement is often large, and cumbersome gearing is required to reduce the step size for precision focusing.

It is an object of this invention to provide motorised focusing apparatus, suitable for application to a camera, without unduly increasing its size.

Focusing apparatus according to the invention, for moving a lens element along its optical axis, includes a lens holder in which the lens element is mounted, a lens holder support coupled to the lens holder so that the lens holder is moved axially in response to relative rotation of the lens holder and support, and an electric motor arranged to effect the said relative rotation at a speed less than the speed of rotation of the motor, characterised in that the motor is an epicyclic motor having a stator concentrically disposed with respect to the optical axis of the lens element, an armature which, when the motor is energised, is eccentrically disposed around the said axis, and means whereby the armature effects relative rotation of the lens holder at the said reduced speed.

In the preferred apparatus embodying the invention, the epicyclic motor includes a plurality of pole pieces and means whereby the pole pieces are energised in a sequential pulsed manner to impart an eccentric rotation to the armature within the stator, the number of pulses applied to the motor being indicative of the position of the lens along the said axis. In this embodiment, the armature has two rings of teeth by means of which it simultaneously engages teeth on a fixed armature support, centrally mounted in the stator, and teeth on the lens holder. The pulses applied to the stator poles cause the armature to roll around the armature support,

Such a construction permits automatic focusing mechanism to be arranged co-axially around a lens system and hence packaged compactly in a relatively small space. The pulsed drive permits the mechanism to move the lens element in precise incremental steps to provide accurate focusing without continously interactive feedback.

In order that the invention may be better understood, one example of a photographic camera embodying the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is a perspective view of a camera having an automatic focus drive apparatus embodying the invention;

Figure 2 is a schematic plan view of an epicyclic motor embodying the invention which shows the position of the lens and lens holder relative to the rotating armature;

Figure 3 is a cross section along lines 3-3 of Figure 2, showing the relationship between the various fixed and movable lens mounts, the armature, and other elements of the epicyclic motor;

Figure 4 is a 90° cut-away perspective view of the epicyclic focusing mechanism of the camera as seen along lines 4-4 of Figure 2 and showing the epicyclic motor modified to embody the invention; and

Figure 5 is a block schematic diagram of electrical equipment for driving the incrementally driven motor.

Referring to Figure 1, a camera 10 includes a lens mount 12 in which a lens holder 14 is positioned for rotating motion. Lens holder 14, which mounts a focusing lens element 16, is supported to move also in a direction parallel to the axis of the lens to focus an image at a camera film plane 22.

Lens element 16 and lens holder 14 are supported and encompassed by, and are co-axial with, an incrementally driven rotating device 28 in the form of an epicyclic motor secured within and to camera 10. The epicyclic motor is mechanically coupled to the lens holder 14 so that the driven rotational motion of an eccentrically mounted rotating armature 36 of the epicyclic motor (Figures 2, 3 and 4) rotates the lens holder 14 and the lens element 16 as a unit. The lens holder 14 is threaded on and thus is secured to a fixed support element 40 (fixed with respect to the stator of the epicyclic motor 28) so that rotation of lens holder 14 moves it, with lens element 16, in a direction parallel to the lens axis, which coincides with the optical axis of the camera.

The illustrated camera also has an automatic range determining device 88, for example the sonic system described in U.S. patent no.3,522,764. The sonic rangefinding system disclosed in U.S. patent no.3,522,764 provides an electrical signal which can operate drive circuits for motor 28 to focus the lens element 16.

The switch 100 shown in Figure 1 is a lever or button the operator depresses, just prior to taking a picture, to turn on the automatic focusing mechanism and thereby automatically bring into focus the image viewed in the camera viewfinder.

Referring now to Figures 2-4, the rotating armature 36 includes a magnetically soft iron sleeve member 41 carried on a central ring gear member 42. A stack of thin laminations 43 is carried on sleeve member 41. The armature thus assembled with sleeve member 41, gear member 42, and laminations 43 is disposed eccentrically within a stator 46 of the motor 28. The stator 46 has circumferentially-spaced and radially-extending pole pieces 48 of thin laminations and a yoke member 49. The stator may have any number of pole pieces 48, each with a coil 50 wound around it. The coils are illustrated in Figure 2 connected electrically in series; the connection point between each pair of adjacent coils is brought out to a terminal diagrammatically illustrated in Figure 2 as a commutator 51.

In the illustrated embodiment, the stator 46 has eight pole pieces 48 concentrically disposed about a fixed center axis A which coincides with the optical axis of the lens element 16. Electrical drive signals are applied to the coils so that one circumferentially-adjacent half of the coils effectively has a first magnetic polarity and the other circumferentially-adjacent half has the opposite magnetic polarity. With the connections shown in Figure 2, where a rotatable pair of brushes 52 are illustrated in electrical contact with diametrically opposite commutators to provide power to the coils 50 of the epicyclic motor 28, the coils and corresponding pole pieces of the left half of the stator have one magnetic polarity while the coils and corresponding poles of the right half of the stator have the opposite polarity. The resultant magnetic field pulls the eccentric armature against lens holder 14 and a fixed support element 54 (Figures 3 and 4) at a circumferential site 55 (Figure 2). As the brushes rotate, making contact with each successive pair of oppositely-positioned commutators, the respective coils are energized in such a manner that the magnetic field between the stator pole pieces rotates synchronously with the brushes. It will be understood that the brushes and commutators, and the series connection of the coils, are shown only in Figure 2 for illustrative purposes. Any of various configurations of electronic circuits preferably is provided in place of the brush-commutator structure. For example, solid-state components known in the art can provide the same rotating magnetic field.

The armature 36 of the motor 28 moves, in response to the rotating magnetic field, around the fixed support element 54 with a rolling motion synchronized to the magnetic field. Since the inside surface of the armature which faces element 54 has a diameter greater than the supporting surface of element 54, the armature will also rotate about its own center as it rolls about element 54. In this manner, the center axis of the armature 36 rotates concentrically about the fixed axis A. The epicyclic motor described thus far is known in the art, and is available, for example, from The Bendix Corporation. Further information concerning it is available in the art.

In the camera system shown the epicyclic motor is adapted to move a lens to focus an image at the camera film plane, as follows. Referring to Figures 3 and 4, the epicyclic focusing motor includes the armature 36 assembled with elements 41, 42 and 43, the stator 46 with pole pieces 48, coil windings 50 and yoke 49, and the fixed support element 54. When adapted for focusing a camera lens, the motor further includes the lens holder 14, the movable focusing lens element 16, a lens holder support or wall element 40, and annular sliding support mounts 64 and 66. These mounts axially position the armature 36 within a support housing 68 of magnetically soft material that typically is secured to the body of camera 10.

The optical light path from an image to the camera film plane 22 passes through the center of the motor, where the movable lens system is located. In this manner, the bulk of the motor is conveniently placed around the outside of the lens system and hence is compactly "absorbed" by the camera body. In this context, fixed support elements 40 and 54 can also mount optical elements of the camera lens system.

As shown in Figures 3 and 4, the armature 36, along the cylindrical circumference where it contacts fixed support element 54, is provided with a first set of internal gear teeth 70 which mesh with corresponding external gear teeth 72 around a circumference of fixed support element 54. The outside diameter of that portion of the armature support 54 which is within the armature is sufficiently less than the armature inside diameter to provide annular spacing between these elements sufficient to accommodate the eccentric motion of the armature. The armature gears mesh with the support gears only along part of the opposed toothed surfaces, due to the eccentric location of the armature about the support. Further, the pitches of the gear teeth 70 and 72, i.e., the number of gear teeth per inch, are approximately the same, i.e., they can be equal or differ slightly, so that as the armature 36 rolls about fixed element 54, it will rotate slowly about its own center.

The armature 36 has a second set of internal gear teeth 78 positioned around a second internal circumference and which mesh with a set of external gear teeth 80 formed around an outside circumference of lens holder 14. The diameters of opposed surfaces of the armature and of the holder 14 differ to provide space between these surfaces as just described for the armature and the support element 54. Similarly, the pitches of gear teeth 78 and 80 are approximately the same, and the gears mesh only along a portion of the opposed surfaces. As noted above, the illustrated lens holder 14 is secured to the fixed lens-holder support element 40 by mating helical threads 86. By properly selecting the diameters of the mechanical components and the pitches of gear teeth 78 and 80 according to known practices, the armature 36 can apply large rotational torques as it rotates the lens holder 14. In this manner a substantial reduction in speed may be provided between the speed of the motor and the speed at which the lens is displaced. This rotational torque can rotate lens holder 14 in either direction and, through its helically arranged threaded connection to fixed support element 40, provides for reciprocal translation of the holder 14 along the optical axis. By appropriate choice of pitch diameters of threads 86 and of the gears, the increment of axial rotation of the lens holder 14 produced by an increment of armature rotation can be made substantially as small as required, e.g., in one instance less than 15 minutes of arc per increment.

Referring now to Figure 5, the illustrated electric system 88 (Figure 1) for generating drive signals to rotate the motor 28 through arcuate increments includes a reset circuit 90, an increment-determining circuit 92, a range-determining circuit 94, and a motor drive circuit 96. The illustrated electrical system is one of several that can be used. The selection of a specific system and the construction of the circuits for it, including thos illustrated, can employ conventional skills known in the art. The reset circuit 90 is independently responsive to closures of switches 100 and 102 to operate circuits 92 and 96 to reset the lens element 16 to an initial predetermined focus position; for example, to either minimum or maximum focus. The operation of the reset circuit 90 is initiated by the closure of the contacts of switch 100, which as noted can be a manual lever-actuated switch located on the camera. Actuation of switch 100 by the operator closes the switch contacts and thereby actuates the reset circuit 90 to apply an "increment" signal level on line 104 to the increment determining circuit. This signal on line 104 serves two functions. First, it actuates the increment determining circuit to produce pulses, on a line 106, which actuate the motor drive circuit 96 to generate signals that reset motor 28 to an initial starting position. Each pulse on line 106 represents one increment of movement, and the pulses are spaced no closer than the minimum time required to increment the motor. Simultaneously, the increment determining circuit actuates the range determining circuitry 94, with signals on a line 108, to produce a signal, on a line 110, indicative of the range from the camera to the image. This latter signal can be provided as described in the above-noted U.S. patent no.3,522,764 or by other apparatus known in the art. The signal on line 110 is processed as described below.

When the lens holder carries the focusing lens element 16 to the predetermined reset position, switch 102 closes to signal the reset circuit that the motor is at its initial reset position. The illustrated switch 102 is a microswitch fixed on the support housing 68 actuated by a pawl 103 carried on the lens holder 14. The reset circuit thereupon provides a "reset complete" signal level over a line 112 to the increment determining circuit. (The "increment" signal level on line 104 is removed at or prior to the time the "reset complete" signal appears, depending on details of the circuit 92.) Upon receipt of the "reset complete" signal on line 112, the increment determining circuit terminates the stream of pulses on line 106 to the motor drive circuit, so that further reset-incrementing of the motor ceases.

Simultaneously, the increment determining circuit 92 converts the range determination signal on line 110, using for example a read-only memory or a non-linear analog-to-digital converter, to a binary number which represents the number of increments which the motor must turn to position the focusing lens element at the specified focus position. The increment determining circuit stores this number, e.g., in a register, and provides a number of pulses on line 114 to the motor drive circuit to rotate the motor armature, and hence the lens holder and lens element, to the correct position. After the number of pulses provided over line 114 equals the binary number stored in the increment determining circuit, the circuit 92 ceases transmitting pulses to the motor drive circuit, which in turn terminates incrementing motor 28 over a plurality of lines 116.

The illustrated motor drive circuit 96 simulates the brush 52 and commutator 51 arrangement shown schematically in Figure 2 by using known solid state devices to arcuately increment the motor 28 more reliably and to reduce the motor size. In the illustrated embodiment, the coils 50 are arranged in a circuit for individual actuation, Figure 5. Thus drive circuit 96 is connected over lines 116 to actuate each coil 50 independently, i.e., there is a separate line 116 to each coil, and there also is a common (e.g., ground) return.

When the motor 28 has reached its correct "in focus" position, the illustrated increment determining circuit provides a signal level over a line 120 which can, for example, signal the user, with an indication in the viewfinder of the camera, that the camera is in focus. At this juncture, a picture is taken. Where desired, an interlock can be provided between the focusing and the picture-taking operations so that a picture is not taken until the camera has reached the focus condition.

As noted above, the range determining circuit 94 can be constructed in the manner disclosed in U.S. patent no.3,522,764, or it can be provided by other known automatic manual control systems. Thus, for example, a manually controlled rangefinder could be used to determine the distance from the camera to the image, and upon closing of switch 100, the increment determining circuit can use that manual setting to effect movement of lens element 16.

In other embodiments, the position of the lens focusing element 16 can be stored in the increment determining circuit by using an up-down digital counter to count the pulses provided over lines 106, 114. In that case, the reset at the beginning of each focus determination can be eliminated. The system instead is reset after electric power is removed, to provide the up-down counter with a known initial starting position.

EXAMPLE

In a particular embodiment of the invention as illustrated, the epicyclic motor has eight stator pole pieces 48 and eight stator coil windings 50. The armature is provided with one hundred and twelve gear teeth 70 at a pitch diameter of 1.1667 inches, and the fixed support element 54 is provided with one hundred and eight gear teeth 72 at a pitch diameter of 1.125 inches. The portion of the armature which meshes with the lens holder is provided with one hundred and four gear teeth 78 at a pitch diameter of 1.0833 inches, and the lens holder itself is provided with one hundred gear teeth 80 at a pitch diameter of 1.0417 inches. This construction produces rotational movement of the lens, in an opposite direction from rotational movement of the armature, of 0.989 degrees per complete cycle of the armature (eight incremental steps), so that after three hundred and sixty-four cycles (2912 increments) the lens element rotates a full 360 degrees; this is the maximum rotation to transport the focusing element over the full focus range. Where the threads 86 have an 0.25 inch lead so that one complete rotation of the lens element 16 advances it by 0.250 inch, then each increment of motor rotation corresponds to an axial movement of the lens element of about 0.00008 inch.

Other embodiments of the invention including additions, substractions, deletions, and other modifications will be obvious to those within the skill of the art and are within the ambit of the following claims.

Although the focusing apparatus of this invention is described in relation to a camera structure, it will be understood that the invention has broader application and may be used in conjunction with other devices such as a microscope.

CLAIMS

1. Focusing apparatus for moving a lens element along its optical axis, including a lens holder in which the lens element is mounted, a lens holder support coupled to the lens holder so that the lens holder is moved axially in response to relative rotation of the lens holder and support, and an electric motor arranged to effect the said relative rotation at a speed less than the speed of rotation of the motor, characterised in that the motor is an epicyclic motor having a stator concentrically disposed with respect to the optical axis of the lens element, an armature which, when the motor is energised, is eccentrically disposed around the said axis, and means whereby the armature effects relative rotation of the lens holder at the said reduced speed.

2. Focusing apparatus in accordance with claim 1, wherein the epicyclic motor includes a plurality of pole pieces and means whereby the pole pieces are energised in a sequential pulsed manner to impart an eccentric rotation to the armature within the stator, the axis of the armature rotating concentrically about the said optical axis of the lens element, the number of pulses supplied to the motor being indicative of the position of the lens along the said axis.

3. Focusing apparatus in accordance with claim 2, in which the epicyclic motor further includes a fixed

armature support centrally mounted within the stator for engaging the armature when the armature is driven in eccentric rotation.

4. Focusing apparatus in accordance with claim 3, comprising coupling means whereby the armature and the lens holder are engaged for rotating the lens holder about the optical axis of the lens element as the armature is caused to roll around the said fixed armature support in response to pulses applied to sequentially energise the motor pole pieces.

5. Focusing apparatus in accordance with claim 3 or 4, wherein the lens holder is formed on one part of its surface with a helical thread for engaging a complementary thread on the lens holder support, and is formed on another part of its surface with gear teeth for engaging gear teeth on the inner surface of the armature.

6. Focusing apparatus in accordance with claim 5, wherein another portion of the inner surface of the armature has gear teeth engaging further gear teeth provided on the said fixed armature support.

7. Focusing apparatus in accordance with any one of the preceding claims, further comprising means for resetting the epicyclic motor to an initial starting position corresponding to a predetermined position of the lens element along its optical axis.

8. Focusing apparatus in accordance with any one of the preceding claims, comprising a focus-determining circuit for providing an electrical output signal representative of the number of arcuate increments required to move the lens element from an initial condition to a position corresponding to a required focussed condition, and pulse-generating means responsive to the focus-determining circuit for generating and applying to the motor the required number of pulses.

9. A photographic camera comprising means

automatically ascertaining the range of an object to be photographed and generating an electric signal containing a number of pulses indicative of the said range, and focusing apparatus in accordance with any one of the preceding claims responsive to the said pulses to move the lens element along its optical axis to a focussed condition.

10. Focusing apparatus for moving a lens element along its optical axis, including a lens holder in which the lens element is mounted, a lens holder support coupled to the lens holder so that the lens holder is moved axially in response to relative rotation of the lens holder and support, and an electric motor arranged to effect the said relative rotation at a speed less than the speed of rotation of the motor, characterised in that the motor includes a stator having a plurality of pole pieces arranged concentrically around the said axis and an armature between the stator pole pieces and the lens holder, and further characterised in that the apparatus includes means whereby the pole pieces are energised in a sequential pulsed manner to impart rotation to the armature and thereby to effect relative rotation of the lens holder and support at the said reduced speed, the number of pulses supplied to the motor being indicative of the position of the lens along the said axis.

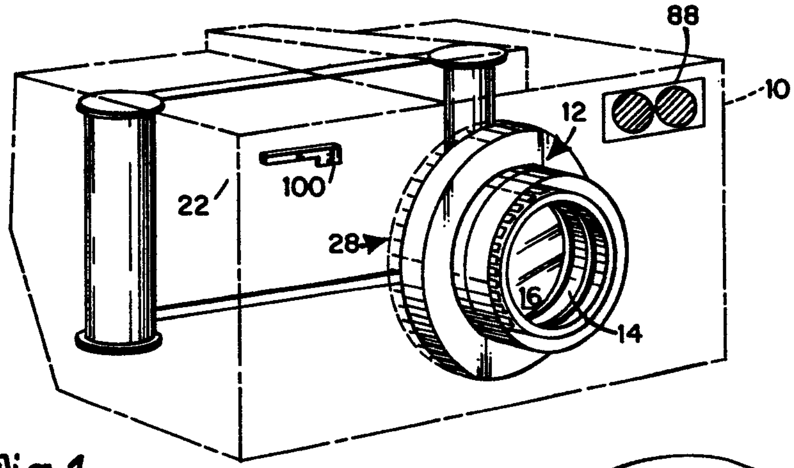


Fig.1.

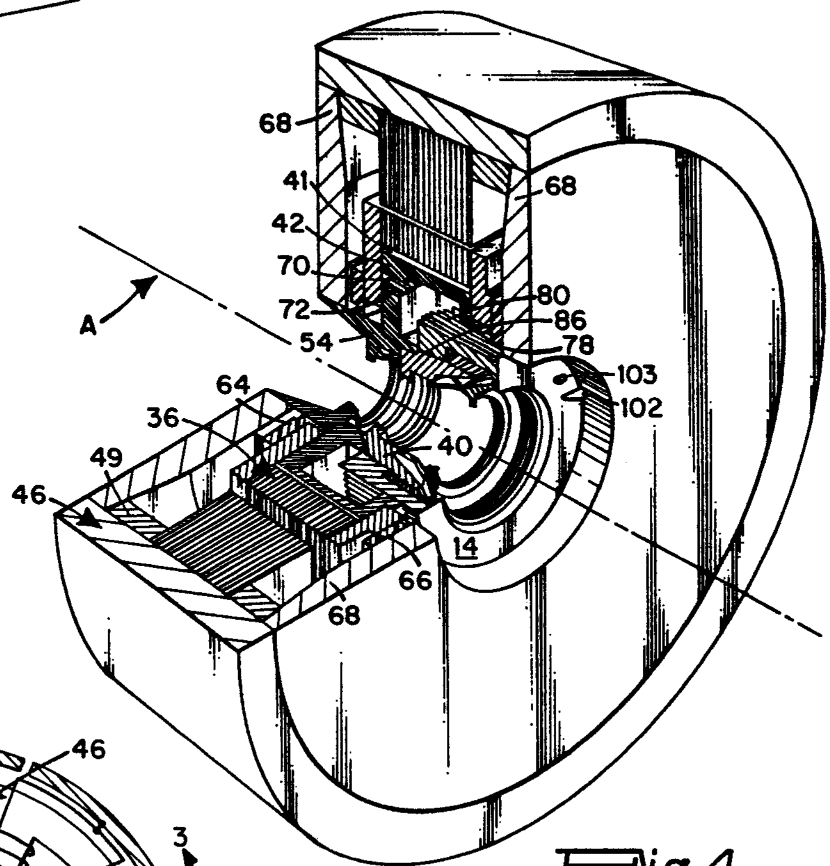


Fig. 4.

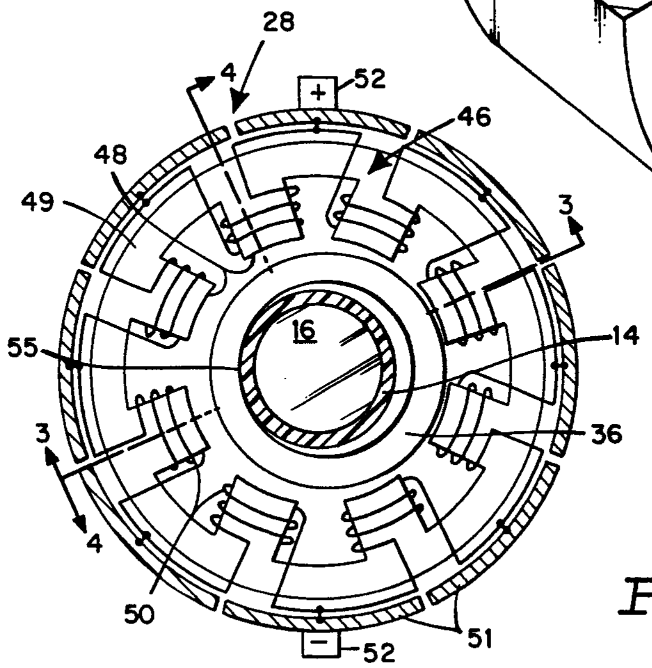
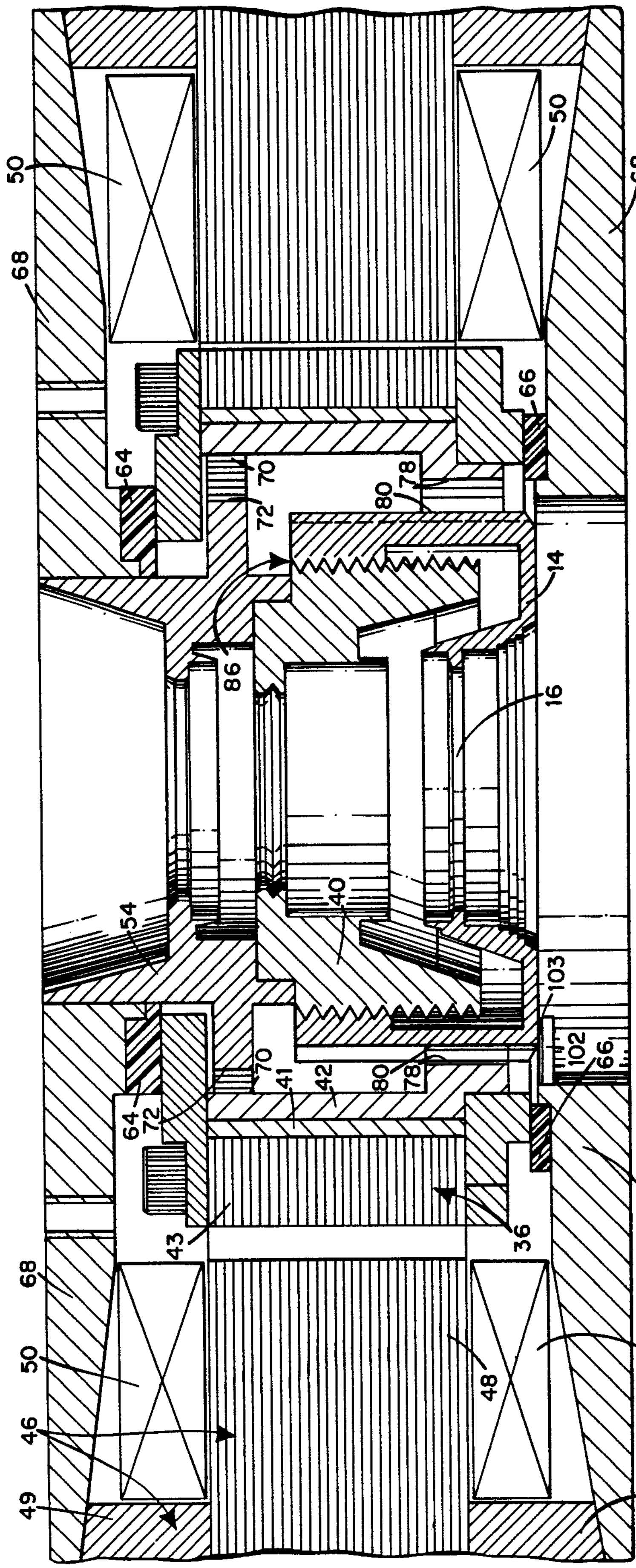


Fig. 2.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68
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Fig. 3.

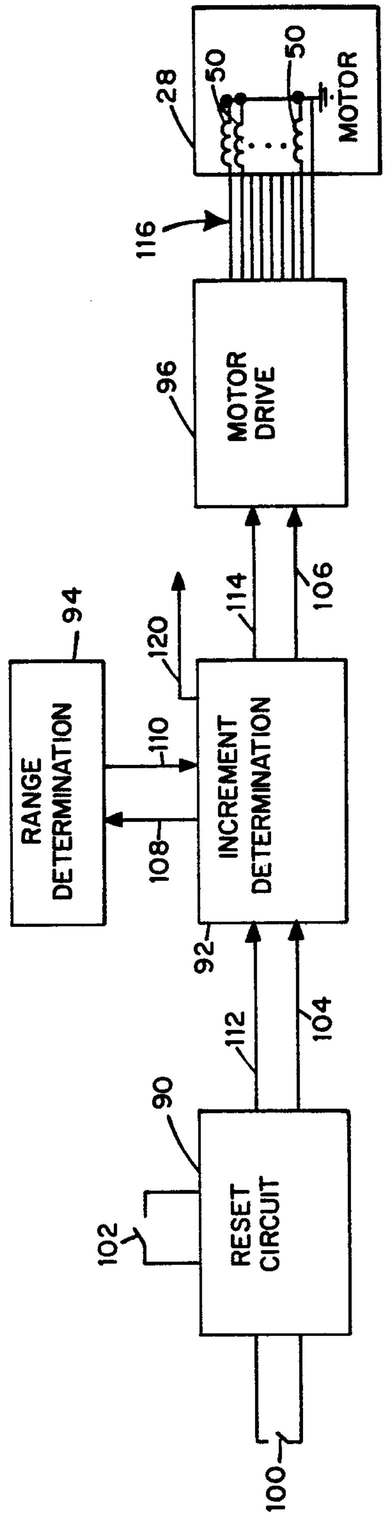
RANGE DETERMINATION
94
110
108
120
114
106
INCREMENT DETERMINATION
92
112
104
RESET CIRCUIT
90
102
100
MOTOR DRIVE
96
116
28
50
MOTOR

Fig. 5.

European Patent Office

EUROPEAN SEARCH REPORT

0000982

Application number EP 78 300 232.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
-	US - A - 3 917 394 (DISPLAY ENTERPRISES) * claims 1,2; column 4, line 32-38; fig. 1, 6 * --	1,10
-	US - E - 27 446 (WELCH) * claim 2; fig. 1 * --	1,2
-	DE - A - 2 346 386 (KOIKE SEIKI) * claims 1, 13; fig. 1, 2 * --	1
A	DE - B - 2 234 448 (REICHERT OPTISCHE WERKE) * column 3, line 35-52; column 5, line 20-49 * --	
A	DE - B - 2 004 343 (BENDIX) * fig. 1; column 3, line 5-10 * --	
DA	US - A - 3 522 764 (POLAROID) * fig. 1, 3 * ----	

CLASSIFICATION OF THE APPLICATION (Int. Cl.²)

G 03 B 13/20
G 03 B 3/10
G 02 B 7/11
H 02 K 41/06

TECHNICAL FIELDS SEARCHED (Int.Cl.²)

G 02 B 7/04
G 02 B 7/10
G 02 B 7/11
G 03 B 3/10
G 03 B 3/12
G 03 B 13/16
G 03 B 13/18
G 03 B 13/20
H 02 K 37/00
H 02 K 41/02
H 02 K 41/06

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	2-11-1978	HOPPE

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