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(54) Title: LINEAR GUIDE

(57) **Abstract:** A linear guide comprises a bearing element and a slide which is reciprocably slidable, by means of balls, relative to the bearing element in a defined direction, along the Z-axis. For each ball a movement space is present between the bearing element and the slide, in which space a force field is present, so that for the ball a preferred position in this space exists, and wherein, as soon as the ball leaves this preferred position, a force is exerted on the ball by the force field, which force is directed substantially towards the middle of the preferred position.

Title: Linear guide

The present invention relates to a linear guide, comprising a bearing element and a slide which is reciprocably slidable, by means of balls, relative to the bearing element in a defined direction, along the Z-axis. The Y-axis is defined as the axis in the direction from the bearing element to the slide, while the X-axis is perpendicular to a plane through the Z-axis and the Y-axis.

When in such a linear guide the balls are received in a cage, there is friction present between the cage and each ball and, in the case where the Z-axis coincides with the vertical direction and the slide is reciprocated relative to the bearing element many times, the cage with balls will have a preference for creeping down between the bearing element and the slide. To limit this effect, an end stop will be present, so that a further creeping down is limited. However, this is accompanied by a certain slip and hence a sudden increase of the friction in the movement of the slide relative to the bearing element, so that the positioning accuracy is jeopardized.

The object of the invention is to prevent this disadvantage at least to a predominant extent and to provide a linear guide in which the occurring friction by which the positioning accuracy is jeopardized is further limited.

According to the invention, to that end, the linear guide such as it is described in the opening paragraph hereof is characterized in that for each ball a movement space is present between the bearing element and the slide, in which space a force field is present, so that for the ball a preferred position in this space exists, and, as soon as the ball leaves this preferred position, a force is exerted on the ball by the force field, which force is directed substantially towards the preferred position.

Such a force field can be obtained by the shape of the space, in which case the linear guide is characterized, according to the invention, in that for each ball a movement space is present between the bearing element and the slide, which space has a shape where there exists for the ball a preferred position in this space, and, as soon as the ball leaves this preferred position, a force is exerted on the ball by the walls of the bearing element and/or the slide, which force is directed substantially towards the preferred position. Accordingly, a cage for the balls is then redundant here.

The force field mentioned, however, instead of being obtained by the shape of the space mentioned, can also be obtained through a varying stiffness of this space, or, for instance, through a magnetic force field. In all cases, however, the force field should dominate gravity and other accelerating forces. For instance by providing a number of magnets on the outside of the movable slide, such that the highest magnetic flux density is obtained adjacent the preferred position of the balls, then, notwithstanding that the space between the movable slide and the bearing element may be formed by parallel walls, the balls are yet held in position. Similarly, the balls in such a space can be held in position when, for instance, the wall of the movable slide entering into contact with the balls is manufactured from a material having a stiffness decreasing in the direction of the preferred position of the balls.

When the balls perform a displacement in the direction of movement of the slide relative to the bearing element, i.e., in the Z-direction, they will leave their preferred position. Due to the slide being relatively elastic in a direction perpendicular to the direction of movement, it is rendered possible, on the one hand, that they can leave their preferred position, and, on the other hand, that they are forced to return to this preferred position.

In particular, a movement space is narrowed starting from the preferred position of a ball in this space, to both sides in the direction of the Z-axis and to both sides in a direction along the X-axis, perpendicular to a plane through the Z-axis and the Y-axis in a direction between the bearing element and the slide.

A movement space is formed by a groove in the bearing element and/or in the slide, extending along the Z-axis, and by a groove in the bearing element and/or in the slide, extending along the X-axis.

Preferably, a movement space is formed by a sidewall of the bearing element with a V-shaped groove extending along the Z-axis and a V-shaped sidewall of the slide, as well as by a V-shaped groove extending along the X-axis in the side wall of the bearing element. Then the apical angle of the V-shaped groove extending along the Z-axis in the sidewall of the bearing element and the apical angle of the groove in the sidewall of the slide can have a value which is between 110° and 170° and which is preferably about 140°, and the apical angle of the V-shaped groove extending along the X-axis in the sidewall of the bearing element can have a value which is between 170° en 178° and which is preferably about 174°.

Although the number of balls in the linear guide can be freely chosen, it is preferred when on opposite sides between the bearing element and the slide two balls are present. Problems of overdetermination and a higher friction possibly resulting therefrom are thereby avoided.

Although unnecessary and even undesirable for most applications, there may be present, in particular for testing purposes, an adjustable biasing element for the force which the balls are subject to between the bearing element and the slide. Such a biasing element can be formed by two biasing plates arranged on the slide at a relatively short distance from each other in the Z-direction, the upper ends of the biasing plates being movable towards and away from each other by means of an adjusting element.

In a practical embodiment, the bearing element is connected with the housing of a linear motor and the slidable slide is connected with the movable part of the linear motor.

The invention relates not only to a linear guide, but also to a device for recording and/or reproducing information, comprising a head for reading information from and/or writing information on a medium, a frame and a linear guide for guiding the head relative to the frame along a straight line, the linear guide being constructed in a manner such as has been described hereinbefore, and the bearing element being connected to the frame, and the slidable slide being connected to the head. In a specific application, where the medium is formed by a magnetic tape and the head by a magnetic head, the device further comprises means for moving the magnetic tape along the magnetic head and a servo circuit for converting track sensing signals read from the magnetic tape by the magnet, to control signals for the linear motor.

The invention will now be further elucidated with reference to the accompanying drawings. In the drawings:

Fig. 1 shows a linear guide according to the invention;

Fig. 2 shows a cross section of the linear guide in Fig. 1 in the XY plane adjacent two opposite balls;

Fig. 3 shows a cross section of the linear guide in Fig. 1 in the YZ plane through the middle of the balls in their preferred position;

Fig. 4 shows a diagram on the basis of which the operation of the linear guide is explained;

Fig. 5 shows a linear guide provided with a biasing element;

Fig. 6 shows a frame part with a linear motor and a bearing element connected to the housing thereof;

Fig. 7 shows the frame part with the linear motor and the bearing element connected to the housing thereof as represented in Fig. 6, with the balls represented in the positions taken by them;

Fig. 8 shows the frame part with the linear motor and the bearing element connected to the housing thereof as represented in Fig. 7, with a slidable slide arranged over the bearing element and the balls; and

Fig. 9 shows the frame part with the linear motor and the bearing element connected to the housing thereof, with the slidable slide as represented in Fig. 7, with a bracket construction connected to the slidable slide for connecting the slidable slide with the movable part of the linear motor.

In the drawings, corresponding parts are indicated by the same reference numerals.

The linear guide according to the invention represented in Figs. 1-3 comprises a bearing element 1 and a slide 3 reciprocable by means of balls 2 relative to the bearing element 1 in the Z-direction. In the exemplary embodiment shown, on opposite sides of the bearing element two balls are present; these balls are clamped between the side surfaces 4 of the bearing element and the side surfaces 5 of the slide. Naturally, on opposite sides three or more balls may be present; however, the presence of more than three balls may then give rise to inaccuracies and a greater friction, in particular by overdetermination of the system.

In the embodiment represented, both the side surfaces of the bearing element and those of the slide are V-shaped. Naturally, it is also possible to use straight side surfaces and to provide a groove therein; this groove can in principle have any desired shape, but is preferably V-shaped. Moreover, it may suffice to provide a groove in either the side surfaces of the bearing element or the side surfaces of the slide, or on one longitudinal side in a side surface of the bearing element and on the other longitudinal side in a side surface of the slide.

As appears from Fig. 3, also in the direction of movement of the slide 3 relative to the bearing element 1, for each ball a groove is present in the bearing element and/or the slide. In the exemplary embodiment shown, these grooves 6 and 7 are provided both in the bearing element 1 and in the slide 3. These grooves, however, are very shallow. The grooves are represented as being V-shaped here, but may have any desired shape, for instance a curved shape. Through the side surfaces 4 and 5 and the grooves 6 and 7, for each ball 2 a movement space 8 is obtained, in which a preferred position can be pointed out where the ball is located centrally in this space. The extent of this displacement possibility will be partly determined by the material choice. In particular, the slide too is then manufactured from a relatively easily bendable plate material permitting of torsion.

As will be explained in more detail, the linear guide finds application inter alia in situations where the direction of movement of the slide relative to the bearing element is vertical. The negative Z-direction, for instance, then corresponds to the gravitational direction. For one ball 5, this situation is represented in the diagram of Fig. 4. The character of the slide 3 allowing of bending and torsion is there indicated by a spring 9 between the slide 3 and the "fixed external world" 10. Upon a small displacement -dz, gravity produces energy of a magnitude of dA_g = mgdz, where m is the mass of the ball 5 and g represents the acceleration of gravitation. This energy is stored in the spring because it is compressed over αdz, where $\alpha << 1$ because the grooves 6, 7 are very shallow. The force which the spring exerts on the ball is $F_v + ½c\alpha dz$, where F_v is the force which was exerted on the ball for the displacement dz and $½c\alpha dz$ the kextra force which is exerted on the ball as a result of the displacement dz. The energy stored in the spring is $dU = (F_v + ½c\alpha dz)\ \alpha dz$. Because $dU = dA_g$, it holds that $mg = aF_v + ½c\alpha^2 dz$. As the last term in this expression is virtually zero, which means that the stiffness of the spring is unimportant, it holds that $\alpha F_v = mg$. Getting the ball back to the point O (Z=0), i.e., the preferred position, requires $\alpha F_v > mg$. The adjusting effort in the Z-direction is $F_{vz} = \alpha F_v$. Given a bias force in the spring (in the slide, in the exemplary embodiment) of, for instance, 5N and a value of α of 10^{-3}, F_{vz} equals 5.10^{-3}N, which value in the case of balls of 0.03 g amply meets the requirement set, and even to the extent that a high degree of adjusting force is left to deal with the other accelerating forces. The numerical values for m and α mentioned here are useful in particular for an application where a magnetic head is arranged on the slide and where a magnetic tape is guided over the magnetic head, with a large number of tracks for data and track sensing signals. It is then of importance that the magnetic head be accurately positioned relative to the tape. In practice, a servo control is present for that purpose, which can displace the slide relative to the bearing element and can keep it aligned in a particular position relative to the respective tracks on the tape. In general, the apex angle of the V-shaped groove extending along the Z-axis in the sidewall 4 of the bearing element 1, and the apex angle of the groove in the sidewall 5 of the slide 3 will have a value which is between 110° and 170° and preferably approximately 140°, and the apex angle of the V-shaped groove 6 extending along the X-axis in the sidewall of the bearing element 1, and the V-shaped groove 7 in the sidewall of the slide 3 will have a value which is between 170° and 178° and preferably about 174°.

In Fig. 5, for testing purposes, a biasing element 11 is provided on the slide. This biasing element is formed by two biasing plates 12 and 13 arranged on the slide 3 at a relatively short distance from each other in the Z-direction, the upper ends of the biasing plates being movable towards and away from each other by means of an adjusting element 14 in the form of a bolt. For certain applications, it may be desirable to be able to adjust the biasing force F_v.

By means of the linear guide described here, a virtually frictionless movement is obtained, which is of importance in particular when on the slidable slide a magnetic head is arranged for reading information from and/or writing information on a magnetic information carrier. On a magnetic tape, for instance, where very great numbers of tracks, for both data and track sensing signals, are present parallel to each other, a servo control is necessary, by means of which the magnetic head should be controllably displaceable over microns. This servo control comprises a servo circuit, controlled from the track sensing signals read from the tape, which servo circuit provides the control signals for the electric motor by means of which the slidable slide is linearly displaceable in the width direction of the tape.

Fig. 6 shows a frame part 15 with a linear motor 16. The bearing element 1 is fixedly connected with the housing 17 of the motor 16. In the side surfaces of the bearing element 1, spaces 18 with a preferred position for the ball are present. Fig. 7 is a replica of Fig. 6, with the balls 2 represented in the positions assumed by them in the spaces 18.

Fig. 8 is a replica of Fig. 7, but in Fig. 8 the slidable slide 3 is represented while arranged over the bearing element 1 and the balls 2. Fig. 9 in turn is a replica of Fig. 8, but Fig. 9 indicates a bracket construction 19 fixedly connected with the slide 3. This bracket construction 19 extends around the motor housing 17 and is fixedly connected (in Fig. 9 at the back) with the movable part of the motor 16, so that through energization of the motor 16 the slide 3 is displaced relative to the bearing element 1. On the slide 3 or on the front side of the bracket construction 19, a magnetic head can be mounted. By means of track sensing signals read from a magnetic tape, and an associated servo loop, the motor 16 can be controlled and the magnetic head can be appropriately positioned and be held so positioned with respect to the magnetic tape.

The invention is not limited to the exemplary embodiment described here with reference to the drawings, but encompasses all kinds of modifications thereof, naturally insofar as they fall within the scope of protection of the appended claims.

CLAIMS

1. A linear guide, comprising a bearing element and a slide which is reciprocably slidable, by means of balls, relative to the bearing element in a defined direction, along the Z-axis, characterized in that for each ball a movement space is present between the bearing element and the slide, in which space a force field is present, so that for the ball a preferred position in this space exists, and, as soon as the ball leaves this preferred position, a force is exerted on the ball by the force field, which force is directed substantially towards the preferred position.

2. A linear guide according to claim 1, characterized in that the space has a shape where for the ball a preferred position in this space exists, and, as soon as the ball leaves this preferred position, a force is exerted on the ball by the walls of the bearing element and/or the slide, which force is directed substantially towards the preferred position.

3. A linear guide according to claim 2, characterized in that the slide is relatively elastic in a direction perpendicular to the direction of movement.

4. A linear guide according to claim 2 or 3, characterized in that a movement space, starting from the preferred position of a ball in this space, is of narrowed design, to both sides in the direction of the Z-axis and to both sides in a direction along the X-axis, perpendicular to a plane through the Z-axis and the Y-axis in a direction between the bearing element and the slide.

5. A linear guide according to claim 4, characterized in that a movement space is formed by a groove extending along the Z-axis in the bearing element and/or in the slide, as

well as by a groove extending along the X-axis in the bearing element and/or in the slide.

6. A linear guide according to claim 4, characterized in that a movement space is formed by a sidewall of the bearing element with a V-shaped groove extending along the Z-axis and a V-shaped sidewall of the slide, and by a V-shaped groove extending along the X-axis in the sidewall of the bearing element.

7. A linear guide according to claim 6, characterized in that the apex angle of the V-shaped groove extending along the Z-axis in the sidewall of the bearing element, and the apex angle of the groove in the sidewall of the slide has a value which is between 110° and 170° and which is preferably approximately 140° and that the apex angle of the V-shaped groove extending along the X-axis in the sidewall of the bearing element has a value which is between 170° and 178° and which is preferably about 174°.

8. A linear guide according to any one of the preceding claims, characterized in that on opposite sides between the bearing element and the slide two balls are present.

9. A linear guide according to any one of the preceding claims, characterized in that an adjustable biasing element is present for the force which the balls between the bearing element and the slide are subject to.

10. A linear guide according to claim 9, characterized in that the biasing element is formed by two biasing plates arranged on the slide at a relatively short distance from each other in the Z-direction, the upper ends of said biasing plates being movable towards and away from each by means of an adjusting element.

11. A linear guide according to any one of the preceding claims, characterized in that the bearing element is connected with the housing of a linear motor and the

slidable slide is connected with the movable part of the linear motor.

12. A device for recording and/or reproducing information, comprising a head for reading information from and/or writing information on a medium, a frame and a linear guide for guiding the head relative to the frame along a straight line, the linear guide being constructed according to any one of the preceding claims, the bearing element being connected with the frame and the slidable slide being connected with the head.

13. A device according to claims 11 and 12, wherein the medium is formed by a magnetic tape and the head is formed by a magnetic head and the device further comprises means for moving the magnetic tape along the magnetic head and a servo circuit for converting track sensing signals, read from the magnetic tape by the magnet, to control signals for the linear motor.

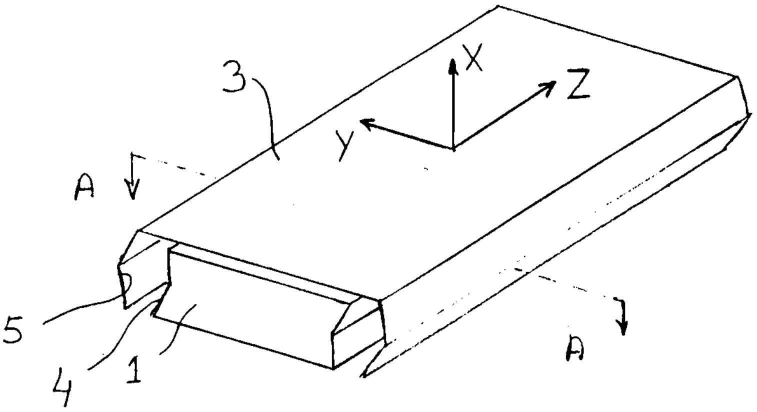

FIG. 1

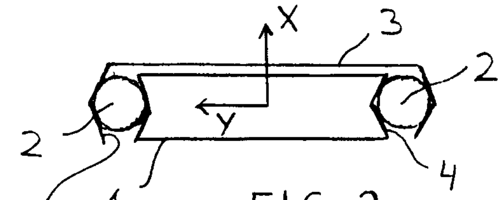

FIG. 2

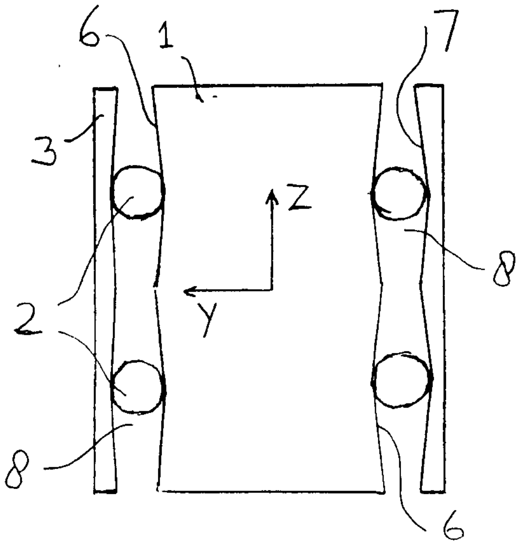

FIG. 3

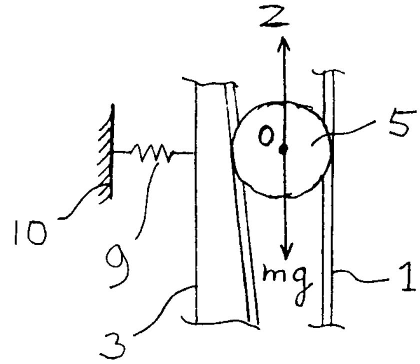

FIG. 4

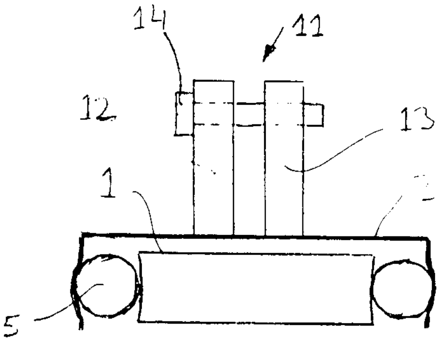

FIG. 5

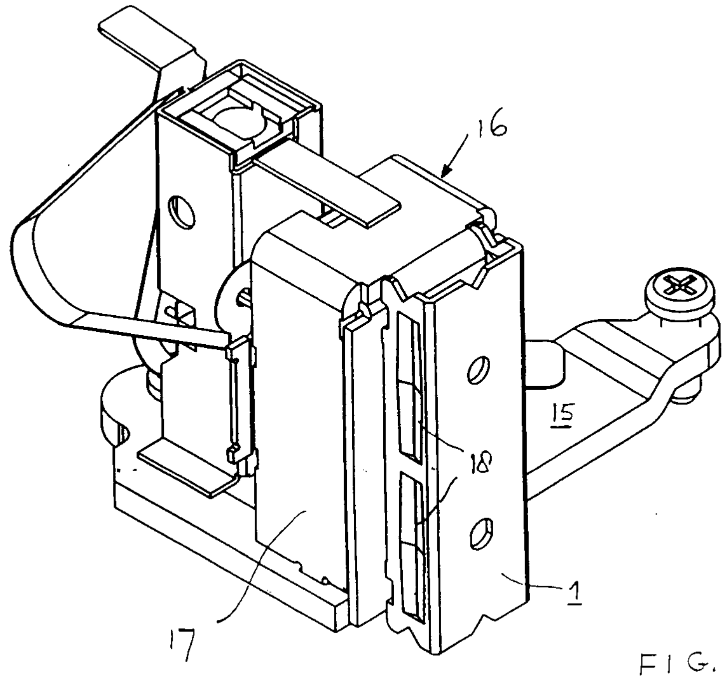

FIG. 6

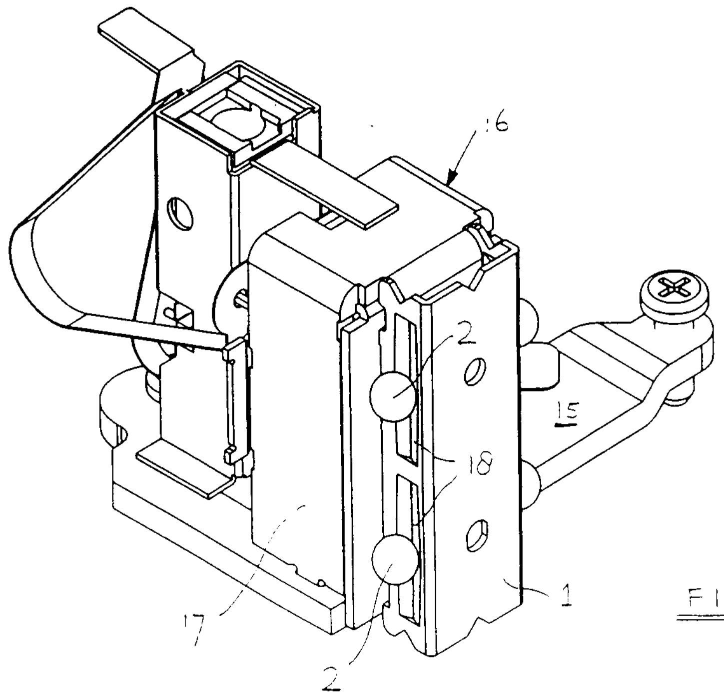

FIG. 7

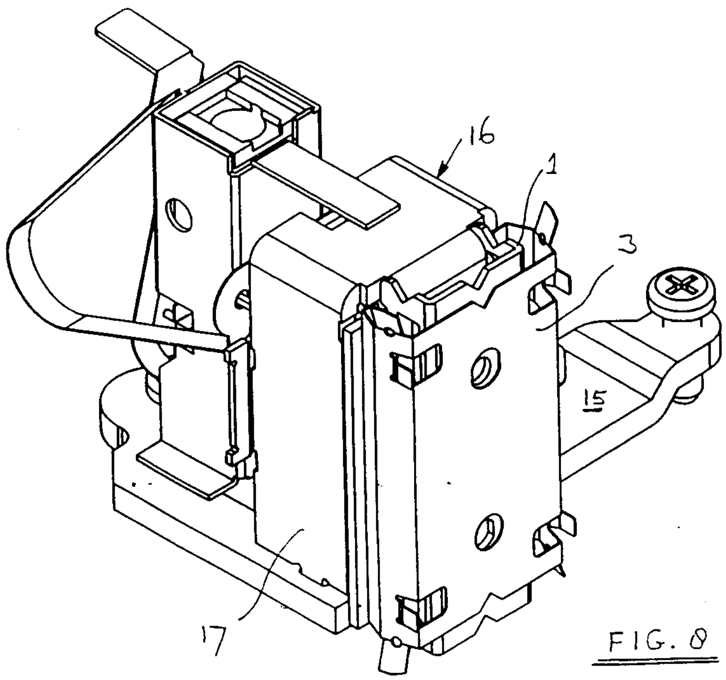

FIG. 8

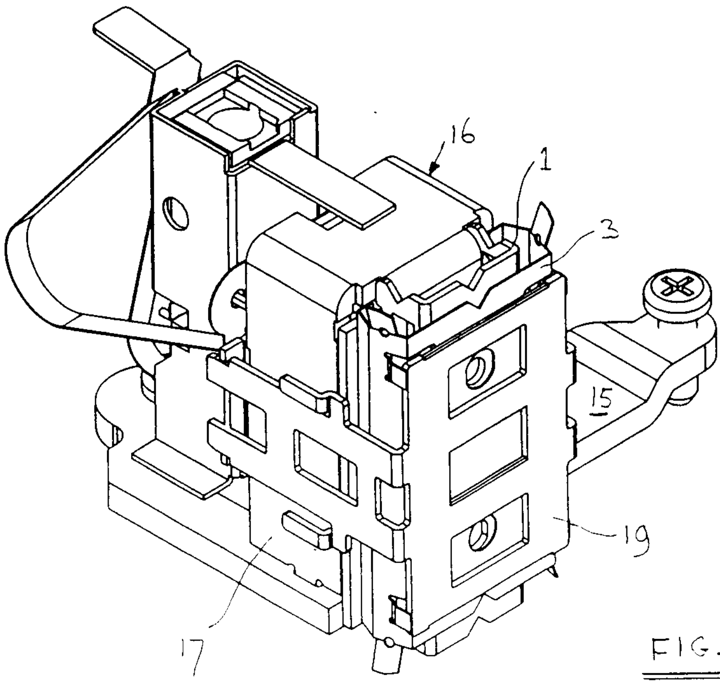

FIG. 9