United States Patent [19]

Dill

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[45] **Jan. 23, 1973**

[54] **ROTATING RING DISPLAY**

[76] Inventor: **Hans G. Dill,** 2870 Tabago Place, Costa Mesa, Calif.

[22] Filed: **May 24, 1971**

[21] Appl. No.: **146,199**

[52] **U.S. Cl.** **58/45,** 58/23, 58/127, 340/373

[51] **Int. Cl.** **G04b 19/20,** G04b 45/04, G04c 3/00

[58] **Field of Search**..........58/23 R, 23 D, 26.5, 50 R, 58/53, 126 B, 127 A; 340/373

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Assistant Examiner—Edith C. Simmons Jackmon
Attorney—Joseph E. Szabo

[57] **ABSTRACT**

An electronic wristwatch in which time is displayed by means of a plurality of separately sealed, independently rotatable, coplanar concentric rings. Each ring carries a plurality of magnetic domains and is independently stepped by a set of electromagnets driven by a multiphase pulse train. Typically, each ring is stepped at a different rate so as to display a different unit of time, this being achieved by suitably scaling the frequencies of the multiphase pulse trains which drive the different sets of electromagnets.

15 Claims, 22 Drawing Figures

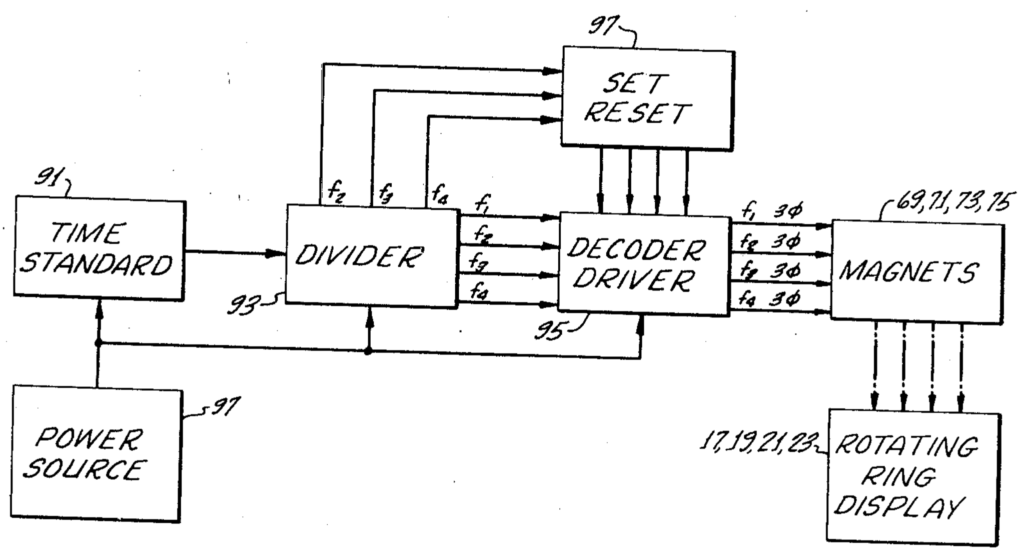
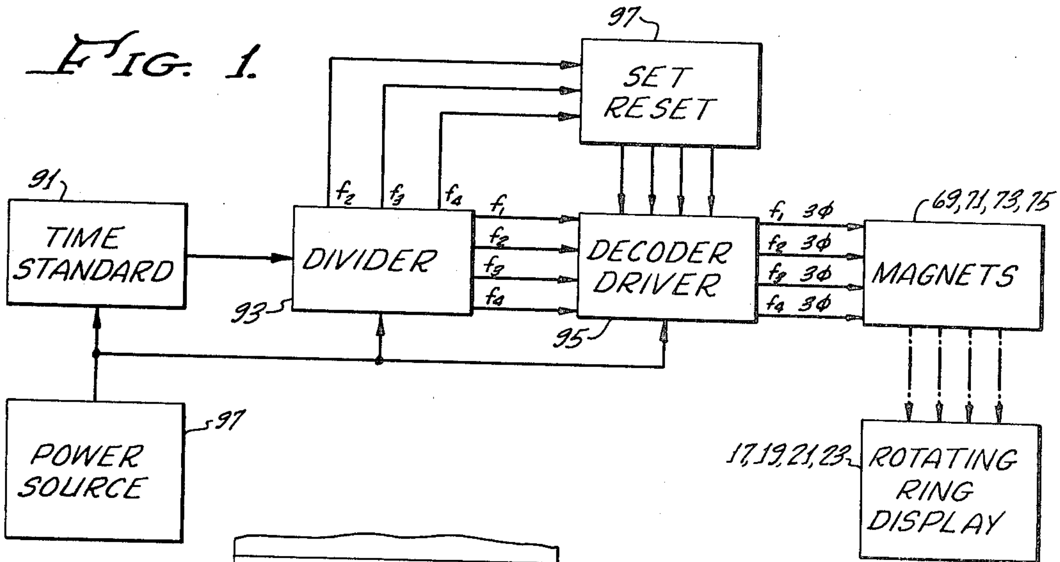


FIG. 1.



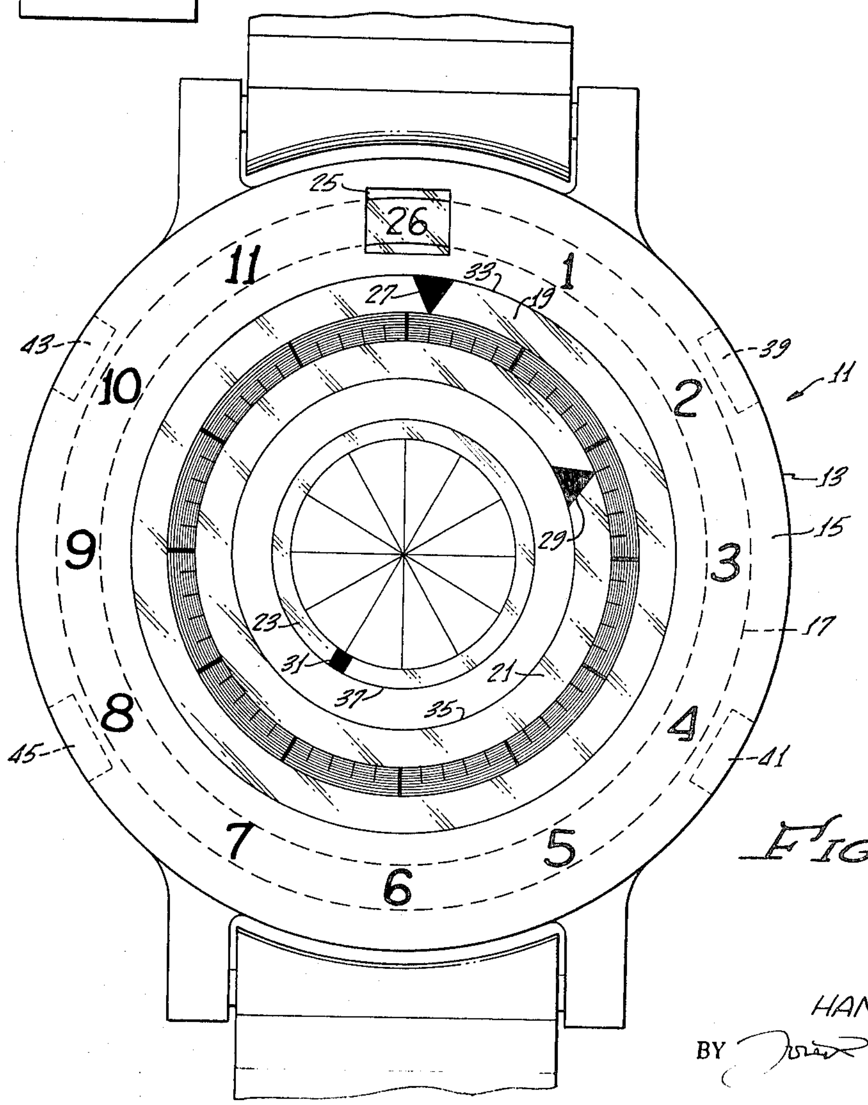


FIG. 2.

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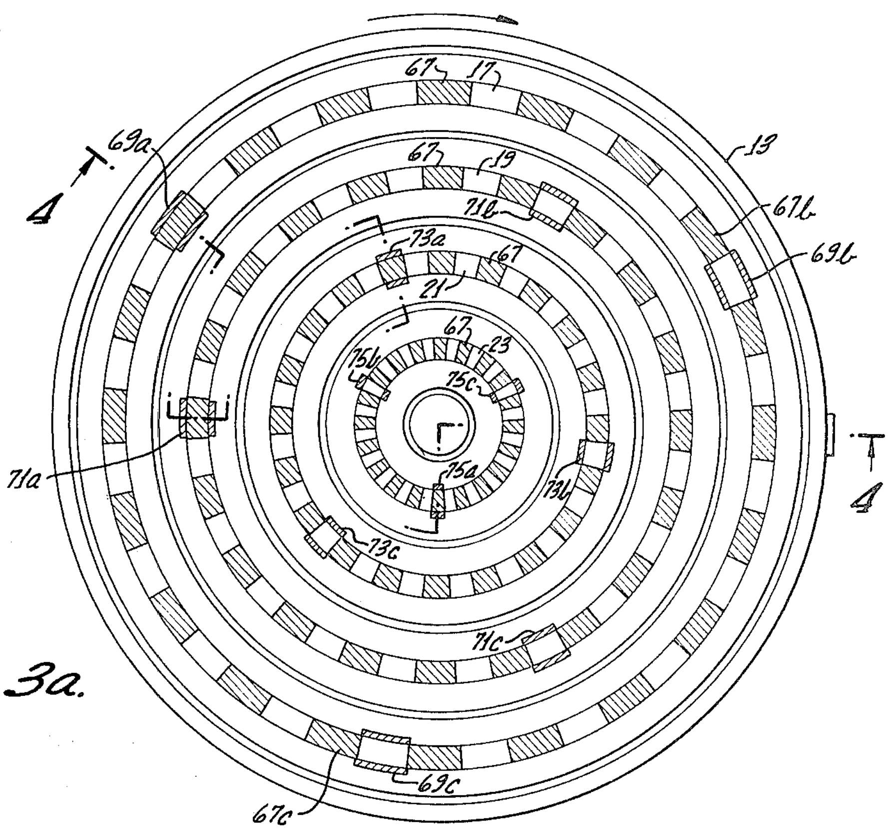

FIG. 3a.

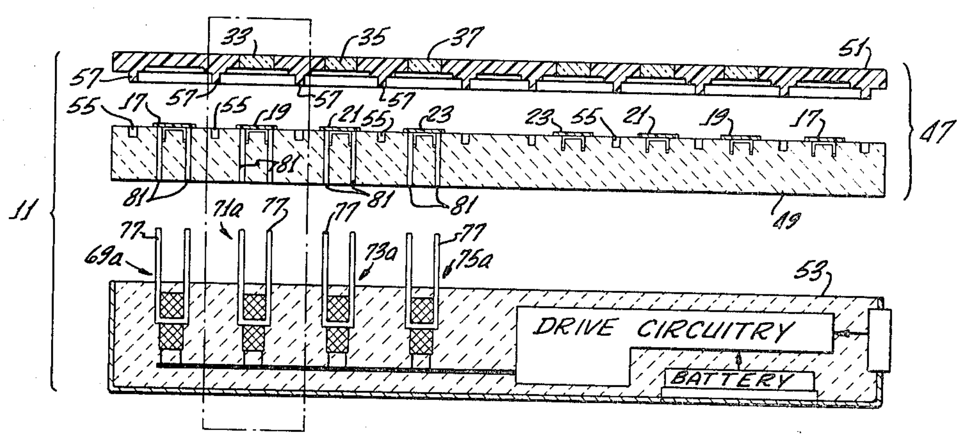

FIG. 4.

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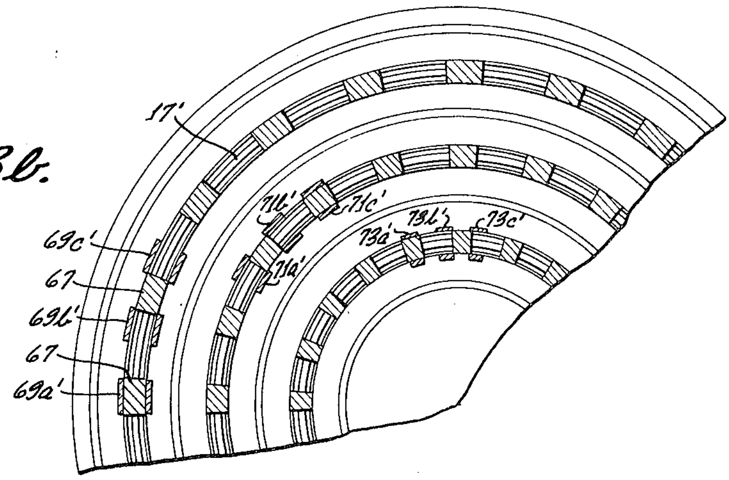

FIG. 3b.

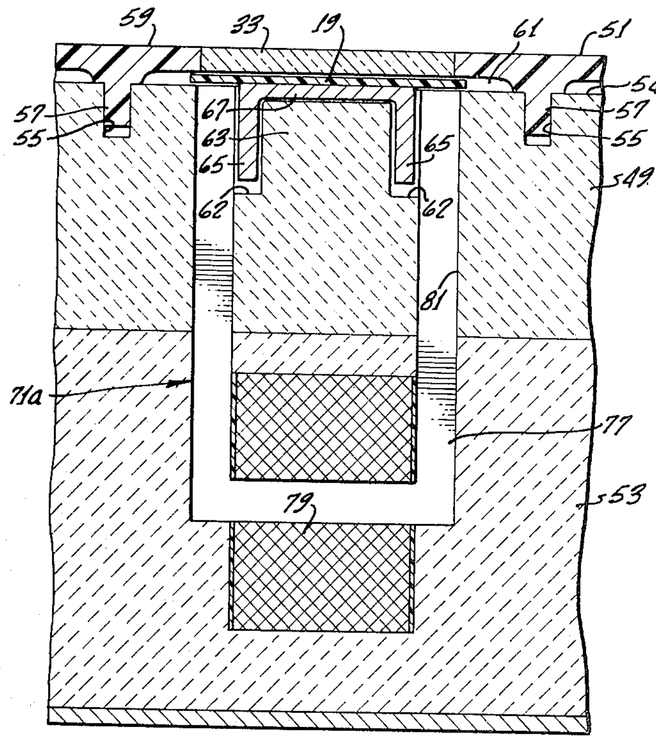

FIG. 5.

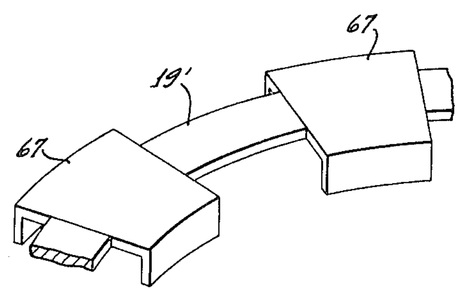

FIG. 6a.

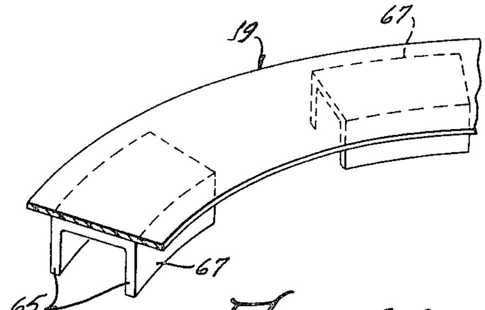

FIG. 6b.

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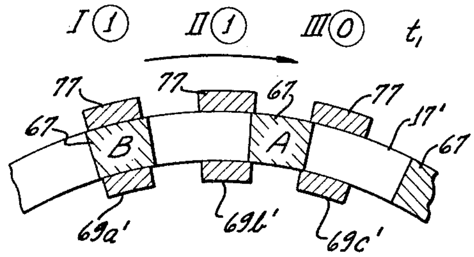

FIG. 7a.

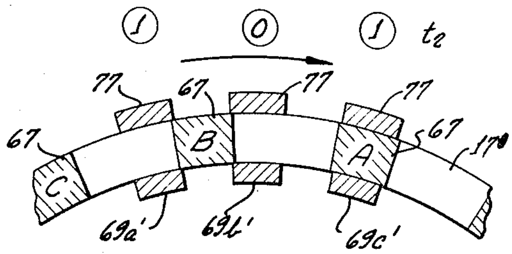

FIG. 7b.

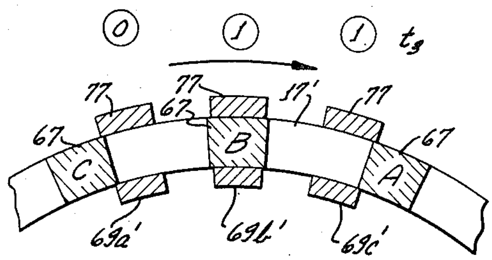

FIG. 7c.

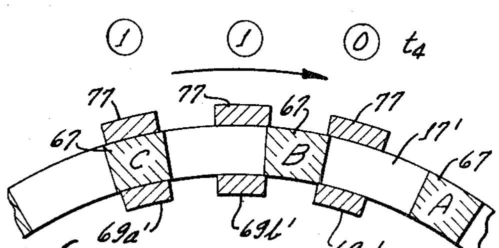

FIG. 7d.

FIG. 8.

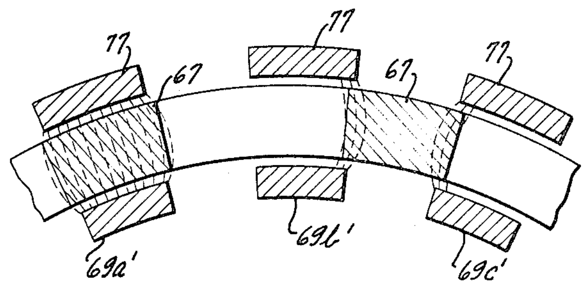

FIG. 9.

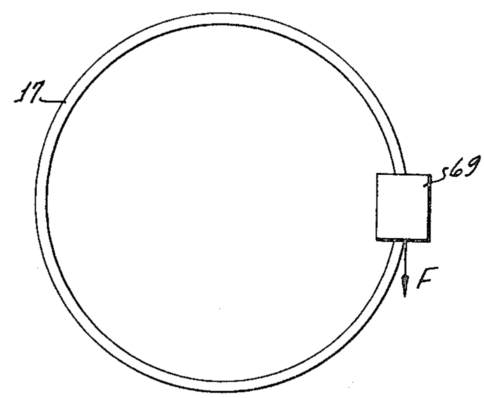

FIG. 10.

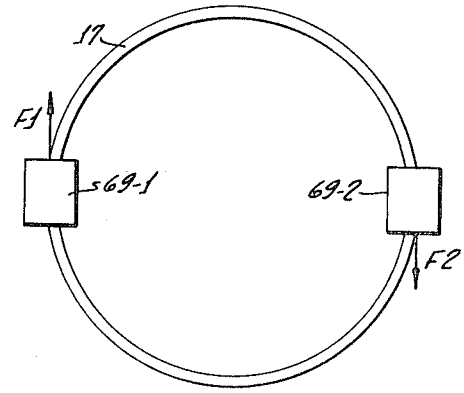

FIG. 11.

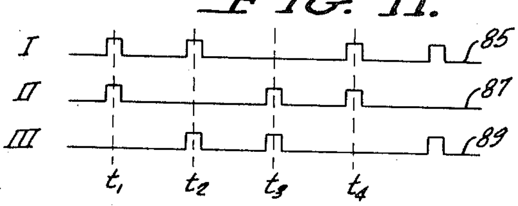

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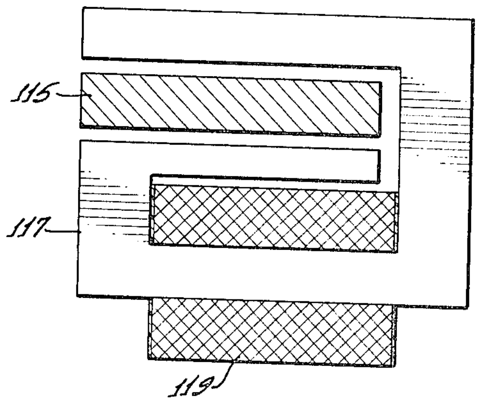
FIG. 14a.



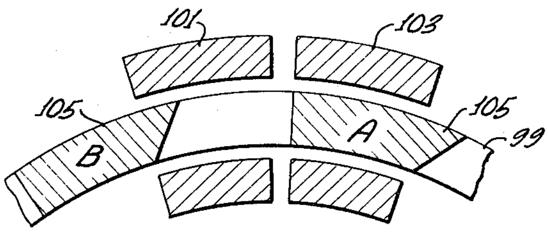


FIG. 12.

FIG. 14b.

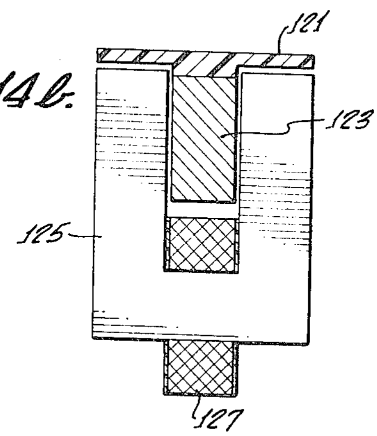


FIG. 13.

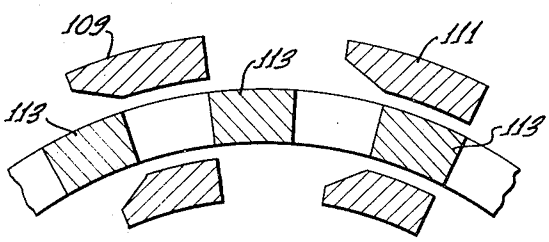
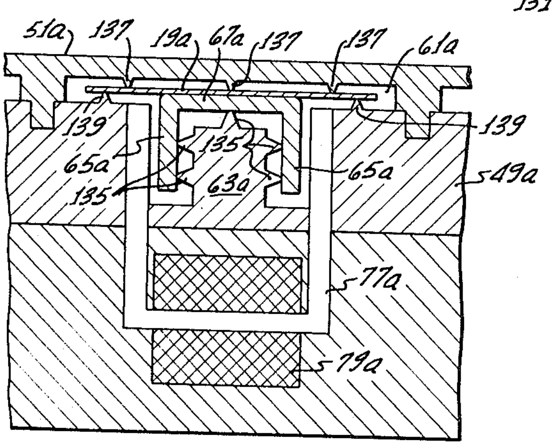


FIG. 15.



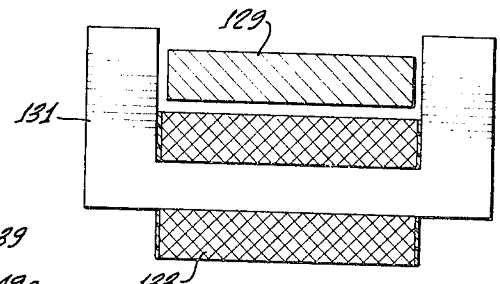


FIG. 14c.

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ROTATING RING DISPLAY

The subject invention relates generally to display devices and more particularly to a device for displaying time.

Until recently, wristwatches indicated time by means of hour, minute, and second hands, rotated through a set of gears around a calibrated watch face by a spring and timed by an oscillating balance wheel. In the past few years, the spring and the balance wheel have been replaced in some watches by an electrically powered oscillating tuning fork, and more recently by a quartz-crystal-electronic divider assembly. Presently there is a great interest in producing a purely electronic watch in which the entire timing process, including the driving of the time display, is done electrically. The electronic portion for the timing portion of such a watch is currently available commercially in the form of miniature integrated circuits using very little power. Batteries capable of powering such circuits for usefully long periods of time have also been developed.

There is still a need, however, for a new type of display whereby the information generated by the electronic circuits of these modern electronic watches can be displayed. Devices currently proposed, such as light-emitting diodes and liquid crystals, each have their shortcomings. Both require relatively complex decoding circuits. Additionally, the light-emitting diode consumes considerable power. Liquid crystals, on the other hand, are stable over only a very small temperature range and require a driving voltage which is presently not suitable in wristwatch applications. Moreover, in their present experimental state, liquid crystal devices tend to deteriorate with age.

It is an object of the present invention to provide an improved display particularly adapted for use with an electronic wristwatch. A related object of the present invention is to provide an electronic wristwatch which, by virtue of its improved display, is simple to manufacture, rugged, and uses a minimum of power.

Another object of the present invention is to replace the hands of a watch and the gears required to rotate them with an alternative display mechanism which is simpler to make, just as easy to read, and readily compatible with the type of signals generated by available electronic time standards.

A basic part of a display made in accordance with the present invention is a rotating ring, carrying indicia which are to be displayed. The ring is advanced in equal steps by an arrangement which includes a plurality of spaced-apart domains on the ring, and driving means adjacent to, but spaced apart from, the ring and operative when electrically energized to exert a thrust upon one or more of the domains so as to advance the ring by one step. Preferably, the domains are magnetic and the driving means includes a plurality of permanent magnets so distributed as to hold the ring stably in a plurality of equally spaced rest positions. Electric coils are wound on the magnets and are alternately energized to modify the effect exerted by those magnets on the domains, thereby causing a net thrust to be exerted on the ring to drive it from a given one of its rest positions to the next such position. It is to be noted that no power is required to maintain the ring in its rest position, this being achieved by the permanent magnet when the coils are deenergized.

An important feature of the present invention is the simplicity and compactness with which several display rings of the type just described are combined into a unitary multi-indicia display. In accordance with this feature of the invention, several rings, each bearing a different type of indicia, such as days, hours, minutes, and seconds, are rotatably supported concentrically within a common flat casing, each ring being preferably sealed separately from the others. Each ring carries a plurality of domains and is provided with an independent driving means such as that described with reference to the single ring display. When the multi-ring display is incorporated into an electronic wristwatch and a magnetic driving arrangement of the aforementioned type is used, the necessary pulses for driving the various rings at their prescribed rates may be readily derived from a single quartz oscillator time standard by electronic frequency dividing and decoder circuits.

The relative positions of the various rings, and in particular of the day, hour, and minute rings are maintained in the necessary synchronism by electronic means rather than mechanically, as in present day watches in which they rigidly intercoupled. Thus the rings, although electronically intercoupled, remain essentially independently rotatable, permitting them to be set independently or in combination and without mechanical means.

The invention will be described in greater detail by reference to the following drawings in which:

FIG. **1** is a block schematic diagram of an electronic wristwatch which indicates time by means of a rotating ring display of the present invention;

FIG. **2** is a plan view of an electronic wristwatch shown in the block schematic diagram of FIG. **1** and illustrating three rotating rings, each having a pointer which moves past a series of numbers or marks, indicating hours, minutes, and seconds, and a fourth ring which carries a series of numbers successively displayed through a window to indicate the date;

FIG **3*a*** is a plan view of a rotating ring display suitable for use in the electronic wristwatch of FIG. **2**;

FIG. **3*b*** is a view similar to view **3**a and illustrating a modification of the rotating ring display in which the driving magnets are differently positioned than those of FIG. **3*a*;**

FIG. **4** is an exploded cross-section along the line **4**—**4** through the time display illustrated in FIG. **3*a*** and illustrates the manner in which the drive circuitry and electromagnetic components are packaged in one casing, and the rotating rings in a second casing which includes a transparent lens;

FIG. **5** is an enlargement of a portion of the three elements illustrated in FIG. **4**, showing them assembled and in particular illustrating the manner in which the magnetic domain of a given ring is magnetically coupled by the core of one of the electromagnets;

FIGS. **6*a*** and **6*b*** illustrate alternative embodiments of the rotating rings carrying spaced-apart domains which are typically magnetic;

FIGS. **7*a*** – **7*d*** are sequential diagrams showing a rotating ring in four successive positions to explain the theory of operation of a three-phase version of the time display;

FIG. **8** is an enlargement of a portion of FIG. **7*d***, showing the flux lines of the magnetic circuit;

FIG. 9 illustrates an asymmetric drive in which all of the magnets of a given ring are located to one side thereof;

FIG. 10 illustrates a symmetric drive in which the ring is driven by two sets of diametrically opposed electromagnets;

FIG. 11 illustrates the phase relationship between the three pulse trains which drive the three-phase electromagnetic drive shown in FIGS. 7*a* – 7*d*.

FIG. 12 illustrates a rotating ring having domains thereon suitable to be driven by a two-phase magnetic drive arrangement;

FIG. 13 illustrates an alternative two-phase drive arrangement in which the pole faces of the driving magnets are shaped to produce a net thrust suitable for driving the ring;

FIGS. 14*a*, 14*b*, and 14*c* are cross-sections through alternative configurations for the time display rings and for electromagnetic means suitable for driving them.

While the invention has been shown and will be described in some detail with reference to preferred embodiments thereof, there is no intention that it must be limited to such detail. On the contrary, it is intended here to cover all modifications, alternatives, and equivalents falling within the spirit and scope of the invention as defined by the appended claims.

Turning now to the figures, an exemplary wristwatch **11** incorporating display rings in accordance with the present invention is illustrated in FIG. **2**. It includes a casing **13** supporting a watch face **15**, below which a plurality of rings, namely, a day ring **17**, an hour ring **19**, a minute ring **21**, and a second ring **23** are rotatably supported in a concentric relationship. Each of the rotatable rings **17, 19, 21,** and **23** carries at least one indicium. In the case of the day ring **17**, there are 31 indicia, one for each day of the month, and these are successively displayed through a display window **25** in the face of the watch. In the case of the other rings **19, 21,** and **23**, only a single indicium is provided, these being shown as the pointers **27, 29,** and **31**, for the hour, minute and second rings **19, 21,** and **23**, respectively. The watch face **15** is appropriately calibrated at least with the numbers **1** through **12**, and the hour, minute and second of the day is indicated by the position of the dots **27, 29,** and **31** next to the watch face calibration. The dots are made visible by annular display windows **33, 35,** and **37**, which are located in registry with and above the respective rings **19, 21,** and **23**. It will be understood, of course, that instead of providing the singular pointers **27, 29,** and **31**, all of the rings, or at least the hour and minute rings **19** and **21**, could be calibrated with indicia representing hours and minutes, and display windows similar to the display window **25** could be provided, thereby permitting the hour and minute of the day to be displayed in the form of a series of numbers.

Each of the rings is rotated in steps at the appropriate rate for that ring, by means to be described. Thus, for example, the day ring **17** may be stepped once a day, the hour ring **19** once every hour on the hour, and so on. Thus, all of the rings are rotated, each at a different rate, but all of them in synchronism with one another so that, for example, the hour ring is stepped when the minute ring is at **60**, and similarly the day ring **17** is stepped every other time that the hour ring passes **12**. Of course, a different relationship may be selected, such as for example the hour ring moving in two equal increments, once on the hour and once on the half-hour.

Means are also provided on the exemplary wristwatch **11** for setting the watch by selectively advancing or retarding one or more of its rings. As will be explained in greater detail hereinafter, pressure-sensitive switches **39, 41, 45,** and **43** are provided on the watch case **13**. Depressing the switch **39** causes the hour and minute rings **19** and **21** to be advanced at a rate which may be changed by the manner in which the switch **39** is depressed. Similarly, the hour and minute rings may be retarded at a desired rate in synchronism with one another by depressing the switch **41**. If it is desired to change the setting of the hour ring only, as when crossing a time zone, the switch **43** is depressed, and similarly, by depressing the switch **45** the date ring **17** may be stepped forward.

Turning next to FIGS. **4** and **5**, the electronic watch of the present invention may be advantageously packaged for ease of manufacture in a first casing **47** containing the rotatable rings **17, 19, 21,** and **23**, and a second casing **53**. The first casing **47** is shown as comprising two principal parts; a ring retainer block **49**, and a lens **51** which is at least partially transparent, in order to render the indicia carried by the rings visible for display. The lens **51** is glued on the ring retainer block **49** and is additionally provided with a plurality of concentric annular tongues **57** which are concentrically arranged on the bottom of the lens **51** and which are received by a corresponding set of concentric grooves **55** in the top surface **54**. As best seen in FIG. **5** and with specific reference to the hour ring **19** which is typical of the other rings **17, 21,** and **23**, the ring **19** is rotatably disposed in an annular groove **62** extending into the body of the ring retainer block **49** from its top surface **54**. A track or bearing **63** extends upwardly from the center of the groove **62** and the ring **19** has a pair of downwardly extending arms **65** so as to keep the ring centered upon the track **63**, which may be lubricated with silicone, for example, to permit the ring to move freely thereon. However, self-lubricating materials, such as nylon or teflon, for the ring or the bearing, or both, are preferable. Conceivably, a layer of air or other gas between the ring and its track might be sufficient for this purpose. One of the annular grooves **55** is disposed radially inwardly from the ring-retaining groove **62**, while another one is disposed radially outwardly therefrom. These grooves and the pair of annular lens tongues **57** together form a pair of annular walls which, together with the top wall **59** of the lens **51**, serves to separately seal the ring-retaining groove **62** and the ring **19** therein. Indeed, it may be seen that the pair of annular seals formed by the tongues and grooves **55** and **57** and by the top **59** of the lens between them, form together with the ring-retaining groove **62** a sealed annular chamber **61** in which the ring **10** is securely and rotatab'y contained.

In accordance with another feature of the invention, the rings are driven in equal steps by providing each of them with a plurality of spaced-apart domains **67** and by further providing for each ring electrically energizable driving means adjacent to that ring and spaced therefrom and operative intermittently to exert a thrust upon one or more of the domains in a direction tending to rotate the ring. The domain and the driving means for exerting a thrust thereupon may be electrostatic, electromagnetic, or even fluidic. In its preferred embodiment, however, as illustrated in FIG. **3**a, the domains are magnetic and are spaced apart equally on each ring. Similarly, the means for driving the rings are also magnetic and are in the form of a set of three electromagnetic devices for each of the rings **17**, **19**, **21**, and **23**. They are identified in FIG. **3**a as **69**a – **69**c for the ring **17**, **71**a – **71**c for the ring **19**, **73**a – **73**c for the ring **21**, and **75**a – **75**c for the ring **23**. In keeping with this aspect of the invention, in its preferred form each of the electromagnetic means, of which the device **71**a may be taken as typical, includes a permanently magnetic core **77** and a coil or winding **79** thereon (FIG. **5**). The permanent magnet **77** associated with each given set of magnetic driving means is operative to exert a holding force upon the ring to which it is adjacent and to exert this force equally in a plurality of rest positions for that ring. In this manner the ring will be held stationary without the need to apply any power to the coils **70** of the electromagnetic driving means. In order to maximize the magnetic coupling between the permanent magnet **77** and the magnetic domains **67**, a pair of slots **81** is provided on opposite sides of the ring-retaining groove **62** in registry with each permanent magnet **77**. Accordingly, when the bottom casing **53** is pushed against the top casing **49**, all of the permanent magnets **77** enter a corresponding pair of slots **81**, and once therein, are closely spaced from the depending arms **65** of the ring **19**. By selecting that portion of the ring **19** carrying the magnetic domain **67** to be also the portion where a pair of depending arms **65** are located, the reluctance of the magnetic path between the arms of the permanent magnet **77** through the magnetic domain **67** is minimized.

The configuration of the ring **19** selected for illustration in FIG. **5** is best shown in FIG. **6**a, in which it is seen to have a relatively wide, thin, and flat configuration and to be carrying a plurality of U-shaped magnetic domains **67** on its underside. The ring **19** is preferably nonmagnetic and may be of plastic. The magnetic domains **67** may also be made of plastic, but containing a magnetic powder. They may be bonded to the ring **19** or may be made as an integral part thereof. And, while they are shown in FIG. **6**a to be narrower than the ring **19**, the domains **67** may also be wider, as shown in FIG. **6**b. The relatively narrow ring configuration results in lighter weight and, hence, smaller inertia. This ring configuration is also illustrated in FIG. **3**b, which is a modification of the watch shown in FIG. **3**a and which differs therefrom in the additional respect of the manner in which its magnetic driving means are located. It will be noted that in the configuration of FIG. **3**a, the individual magnetic driving means of each set, such as the set **69**a – **69**c, for example, are shown as being distributed 120° apart from one another. The purpose of this arrangement is to distribute about the periphery of the ring the thrusts which are exerted upon its domains so as to distribute the torques exerted upon the rings along the periphery and thereby reduce uneven wear on the bearing. Of course, other than a 120° spacing could be selected to achieve the same purpose. Alternatively, it may be desirable from a manufacturing standpoint to locate all of the devices of each set of electromagnetic driving means clustered together, and this is how they are shown in FIG. **3**b, with each set of electromagnetic means having the same reference numerals as its counterpart in FIG. **3**a, but carrying an apostrophe (') to differentiate the two.

The manner in which a given rotating ring is advanced by its associated electromagnetic driving devices is essentially the same for both of the embodiments illustrated in FIGS. **3**a and **3**b. Also, they are the same for all of the rings in a given set of rings and will be explained with particular reference to the day ring **17**', shown in FIG. **3**b as being driven by the set of three electromagnetic devices **69**a', **69**b', **69**c'. These elements are illustrated in greater detail in FIGS. **7**a–b, in which the ring **17**' is shown in four successive positions. Referring first to FIG. **7**a, it will be seen that the electromagnetic devices **69**a'–c' are so spaced that when one of them (**69**a') has a domain **67** centered therein, the other two electromagnetic devices (**69**b' and **69**c') have a domain ahead of and behind them, respectively, by an equal amount. In the case of the ring **17**' of FIGS. **3**b and **7**a, where the electromagnetic devices **69**a'–c' are shown clustered together, it is the same domain (A) which is behind one of the electromagnetic devices (**69**c') and ahead of the other of the electromagnetic devices (**69**b'). Moreover, the domain (A) which is thus situated is next on the ring **17**' to the domain (B) which is centered in the first electromagnetic device (**69**a'). On the other hand, in the embodiment illustrated in FIG. **3**a where the electromagnetic devices **69**a, **69**b, **69**c, are distributed 120° apart from one another, the domain **67**b which is behind one of them (**69**b) is not the same as the domain **67**c which is ahead of the third one of them (**69**c). The principle of operation, however, is the same in both instances. Thus, in both cases the position described is one of equilibrium in which the rotating ring is at rest because no net force is exerted upon it by the permanent magnet **77** of its associated electromagnetic devices, so long as those devices are not energized. Thus, referring again to FIG. **7**a, the permanent magnet **77** of the first electromagnetic device **69**a' exerts no net thrust upon the domain B, because the latter is exactly centered in the former and is in equilibrium. Similarly, no net thrust is exerted upon the domain A, because the permanent magnets **77** of the electromagnetic devices **69**b' and **69**c' exert equal but opposite torques upon it, since they are behind and ahead of it by equal amounts.

It will be understood, of course, that what is meant by a domain being ahead of or behind an electromagnetic device is that the center line of the domain is ahead of or behind the center line of the electromagnetic device. Thus, for example, in FIG. **7**a the trailing edge of the domain A extends slightly into the electromagnetic device **69**b', while its leading edge extends slightly into the electromagnetic device **69**c'. The extent to which it should so extend depends upon the amount of force it is desired that the electromagnetic devices exert upon the domain. This is better illustrated in FIG. **8**, in which the magnetic lines of force are also shown. An advantage of the arrangement just described is that not only is the ring at rest, but it is held there by the permanent magnets **77** and restrained against moving out of the rest position.

The ring **17'** is advanced in steps by successively cancelling, or at least counteracting (and thus diminishing) the force of two of the three permanent magnets **77**, while leaning the force of the third such permanent magnet **77** unaffected. Each time a different one of the three permanent magnets **77** will be left unaffected and, as will be explained, this results in a temporary disruption of the equilibrium of forces, causing the ring to be advanced by one step, which is equal to half the distance between adjacent domains. In the embodiment illustrated in FIGS. **3a** and **3b**, the magnetic effect of the permanent magnet **77** is overcome by energizing the coils **79** wound around the permanent magnets with a short electric current pulse. The first combination of pulses is shown at the top of FIG. **7a** in three circles located above the three electromagnetic devices **69a'–c** '. A zero in a given circle represents the absence of a pulse from the device which is below the circle and, similarly, a "1" in a circle represents the presence of a pulse in the device below that circle. Thus, in FIG. **7a** current pulses are present in the coils of the first two electromagnetic devices **69a'** and **69b'**, while the coil of the third electromagnetic device **69c'** is free of such a pulse. Consequently, since the electromagnetic force exerted by the permanent magnet **77** of the device **69b** has been diminished, while the corresponding force of the magnet **77** of the device **69c'** has been left undiminished, a net forward thrust is exerted upon the domain A and the ring **17'** is moved clockwise, i.e., forward.

FIG. **7b** shows the point at which the ring comes to rest after its forward motion in response to the pulses represented in FIG. **7a**. The reason why the ring comes to rest at that position is that the domain A is now centered in the electromagnetic device **69c'** so that it no longer exerts any thrust, either forward or reverse, on that domain and the domain B is now centered exactly midway between the electromagnetic devices **69a'** and **69b'** and since they are equally energized, they, too, exert no net thrust upon the domain B.

To advance the ring **17'** from its position in FIG. **7b**, the coils of the electromagnetic devices **69a'** and **69c'** are energized. This causes a forward thrust to be exerted upon the domain B by the unenergized electromagnetic device **69b'**, for the same reason that a thrust was exerted in the preceding step on the domain A.

It will be noted that in FIG. 7c the middle electromagnetic device **69b'** has a domain B centered therein, while the left and right electromagnetic devices **69a'** and **69c'** have domains C and A disposed behind and ahead of them, respectively, by equal amounts. Therefore, the ring **17'** is in equilibrium because no force is exerted upon the domain B and equal but opposite thrusts are exerted upon the domains C and A. Hence, to advance the ring from its position shown in FIG. **7c**, the equality of the forces exerted upon the domain C and A is upset by energizing the coil of the electromagnetic device **69c'** but not that of the electromagnetic device **69a'**. The coil of the middle electromagnetic device **69b'** is also energized. As a result, the forward thrust exerted upon the domain C by the electromagnetic device **69a'** exceeds the reverse thrust (if any) exerted upon the domain A by the electromagnetic device **69c'** and the ring **17'** is advanced to its position shown in FIG. **7d**. In this position, the domain C and B occupy the same position as did the domains B and A in FIG. **7a**. Consequently, the coils of the electromagnetic devices **69a'–c'** are actuated by the same combination of pulses which energized them when the ring was in the position shown in FIG. **7a**. Thus, the cycle of energization of the electromagnetic devices **69a'–c'** repeats itself in the same pattern, a pattern which is also shown in FIG. **11**, wherein the pulse trains **85**, **87**, and **89**, respectively, represent the pulses applied to the electromagnetic devices **69a'**, **69b'**, and **69c'**.

Instead of merely neutralizing or diminishing the magnetic force exerted by two out of the three electromagnetic devices **69a'–c'** and leaving t-e third one of them unaffected, an alternative way of driving them could be to pulse the third electromagnetic device also, but in an opposite sense from the way in which the first two electromagnetic devices are pulsed, so that when the first two have their magnetic force diminished, the third one of them has its magnetic force enhanced. This arrangement will, of course, increase the starting torque upon the ring but, at the same time, will also increase the power consumption. Another factor which affects power consumption is the strength of the permanent magnets **77**. The stronger these magnets, the better the stability of the ring in its rest position, but also the greater the current required to neutralize or diminish the magnetic effect of those magnets.

Another alternative driving arrangement is to omit pulsing that electromagnetic driving means in which a domain **67** is centered. Thus, in the example illustrated in FIGS. **7a–7d**, the pulses on the devices **69a'**, **69c'**, and **69b'**, and **69a'**, respectively, would be omitted. Even though the effect would be to leave the "centered" domain in a fully magnetized device, the ring **19** would still be advanced because the net magnetic attraction tending to advance the domain between the electromagnetic devices would be greater than the retarding force exerted upon the "centered" domain. The advantage of this arrangement would be that only half as many driving pulses would be required. It might be noted that the remaining pulse might be either an "enhancing" pulse tending to increase the magnetic effect of the device to which it is applied, or alternatively, a "diminishing" pulse having the opposite effect.

Since the rotatable rings have no central bearing, a magnetic drive, such as that illustrated in FIGS. **3a** and **3b**, will introduce a lateral force, because there is always only one electromagnetic device exerting a thrust upon one of the domains of the ring at any given time. This is illustrated in FIG. **9**, which an electromagnetic device exerting a net lateral force F upon a ring **17** is represented by the numeral **69**. The ring bearing, such as the track **63** in FIG. **5**, if properly designed will be able to support this force without causing the ring to bind. However, friction because ring and track may be further reduced by providing a symmetrical drive arrangement such as that illustrated in FIG. **10**, rather than an asymmetrical arrangement such as that shown in FIG. **9**. In the symmetrical drive arrangement of FIG. **10**, two diametrically opposed sets of drive means **69–1** and **69–2** are provided for a given ring **17**. Each of the devices **69–1** and **69–2** may be of the type shown in FIG. **3b**, for example, and their individual electromagnetic devices will be actuated in succession in pairs; one device from each of the sets **69–1** and **69–2**. Therefore, at all times equal but opposite forces (F1 and F2) will be exerted upon the ring **17**, so that there will be no net lateral force exerted thereupon. Alternatively, several groups, each having two diametrically opposed sets, might be provided.

The electronic circuitry for generating the pulse trains, such as those shown in FIG. **11**, necessary to drive the electromagnetic devices associated with the rings, are well within the reach of those skilled in the art and will not be described in detail. Their arrangement, however, is shown shown in FIG. **1**, in which the set of magnets **69**, **71**, **73**, and **75**, associated with the rotating rings **17**, **19**, **21**, and **23**, are driven from a single time standard **91**. The output of the time standard **91**, which may be a quartz oscillator, is converted by a frequency divider **93**, such as a binary counter, into as many frequencies as there are rotating rings. Typically, the respective frequencies $f1$, $f2$, $f3$, and $f4$, for the second, minute, hour and day rings **23**, **21**, **19**, and **17**, will be one per second, one per minute, one per hour, and one per day, respectively. Each of the frequencies $f1$–$f4$ is converted by means of a decoder driver **95** into a three-phase pulse train, such as that illustrated in FIG. **11**, and each three-phase pulse train is applied to the three electromagnetic devices associated with the appropriate one of the four rotating rings **17**, **19**, **21**, and **23**. A common power source **97**, such as a battery, energizes the components **91**, **93**, and **95**.

One of the advantages of the display system of the present invention is that each of its display rings may be set individually or in any desired combination of two or more, and that this may be accomplished without any mechanical means. The desired setting of the rotating rings may be achieved electronically by means of a set-reset circuit **97**, by means of which selected ones of the frequencies produced by the divider **93** may be applied to the decoder driver **95**, so as to cause those frequencies to be converted by the latter into a three-phase drive train for application to the selected ones of the electromagnetic devices **69**, **71**, **73**, and **75**. Thus, for example, if it is desired to advance the hour ring **19** by 3 hours, typically there will be introduced through the set-reset circuit **97** into the decoder-driver **95** that number of pulses which is required to advance the hour ring the requisite number of times to bring about a change in its display position of 3 hours. Typically, three pulses will be required.

Normally, the minute ring **21** is coupled to the hour ring **19** electronically, in order that when the hour ring **19** is advanced, the minute ring **21** will be at its 60-minute position, as in a conventional watch. This is achieved electronically by maintaining synchronism between the pulses which drive the electromagnetic means associated with the hour and minute rings **19** and **21**, respectively. Such synchronism is maintained by appropriate circuitry within the decoder-driver **95**. When the watch **11** is to be set in the conventional manner, either to initially set the watch or to adjust for a loss or gain of time, the hour and minute rings **19** and **21** must be turned clockwise or counter-clockwise together, with their relative positions remaining unchanged. This may conveniently be achieved by a pair of controls such as the controls **39** and **41** shown on the right-hand side of the watch **11** in FIG. **2**.

Both of the controls **39** and **41** may be pressure-sensitive, temperature-sensitive, or capacitive sensing elements. Each of the elements **39** and **41** is operative to cause the set-reset circuit **97** to introduce a proper pulse from the divider **93** into the decoder-driver **95**, to advance or reset both of the rings **19** and **21**. Specifically, the element **39** may serve to advance the rings **19** and **21**, while the device **41** may serve to set them backward. Advantageously, circuitry may also be provided in the set-reset block **97** to respond differently to pressure upon the devices **39** and **41**, depending upon the length of time that such pressure is applied. Thus, a relatively short actuation of either of the devices **39** and **41** (less than 3 seconds, for example) may cause the hour and minute rings **19** and **21** to move 1 minute. Then, if actuation is maintained for a period of time longer than, say, 3 seconds, the hour and minute rings **19** and **21** may be caused to move by the circuitry provided for that purpose in the block **97**, at an accelerated rate, such as between 10 and 60 minutes per second, so long as such pressure continues to be applied. This two-speed time setting provision permits fast and yet accurate adjustment of time without eye strain. Typically, where a relatively large adjustment of time is required, the proper one of the pressure-sensitive devices **39** and **41** would be depressed for a relatively long period of time to bring about the high rate of adjustment, and when the rings **19** and **21** have been brought to approximately their proper position, the pressure-sensitive device would be released and again depressed for one or more short periods, to drive the rings to their precise desired position by one or more 1 minute steps.

Where only the hour ring **19** is to be adjusted, as for example where a time zone is being crossed, a separate pressure-sensitive device, such as the device **43** on the upper left of the watch **11**, may be used. The pressure-sensitive device **43** is also electrically connected to the set-reset circuit **97**, so as to cause the hour ring **19** to be advanced, by 12 minute steps, for example, in response to each short pressure pulse upon the device **43**. Accelerated advancement of the hour ring **19** may be achieved by prolonging the pressure upon the device **43**. If only one ring is adjusted, the synchronous relation between it and the other rings is controlled electronically. Another pressure-sensitive device **45**, shown at the lower left of the watch **11** in FIG. **2**, may be provided to set the date ring **17** in the same manner as the hour ring **19**.

Many modifications of the disclosed system are possible; for example, instead of using a three-phase electromagnetic drive, a two-phase drive such as that illustrated in FIGS. **12** and **13** may be employed. The drive shown in FIG. **12** consists of two electromagnetic devices **101** and **103** and a ring **99** having magnetic domains **105** thereon. Each of the electromagnetic devices **101** and **103** includes a permanent magnet typically U-shaped, as the magnetic **77** of FIG. **5**. Additionally, each of the devices also includes a coil (not shown) such as the coil **79** of FIG. **5**. Each of the magnetic domains **105** is so shaped as to insure that any torque exerted by the electromagnetic devices **101** and **103** upon the ring **99** will be clockwise. To step the ring **99**, the electromagnetic devices **101** and **103** are alternatively pulsed so as to alternately diminish or eliminate their magnetic effect. The position shown in

FIG. **12** represents a rest position for the ring **99** in which it is held stationary by virtue of the fact that the domain A is centered in the electromagnetic device **103**. To advance the ring one step from its position shown in FIG. **12**, a pulse must be applied to the coil of the electromagnetic device **103**. This diminishes the holding force of that device upon the domain A and permits the domain B to be pulled clockwise by the electromagnetic device **101**.

Alternatively, instead of shaping the domains **105** as in FIG. **12**, the electromagnets of the electromagnetic devices **109** and **111** may be shaped instead. The pulsing sequence remains the same and the devices **109** and **111** are alternatively pulsed in order to alternately diminish the magnetic effect of one relative to the other (FIG. **13**).

The configuration of the rotating rings and of the electromagnetic devices used to drive them may also be varied considerably from that shown in the preceding figures. In FIG. **14***a* a flat ring **115** is driven by an electromagnetic device having a permanent magnet core **117**, shaped somewhat like an inverted G and having a coil **119** on its bottom leg.

A T-shaped ring **121** having a shank **123** is shown driven by a U-shaped permanent magnet **125** having a coil **127** wound around its bottom, in FIGS. **14***b*. This arrangement has the advantage of a large display area and a good bearing being provided by the U-shaped permanent magnet **125**.

Yet another possible configuration is shown in FIG. **14***c*, in which a flat ring **129**, similar to the flat ring **115** of FIG. **14***a*, is driven by a permanent U-shaped magnet **131**, having a coil **133** around its center portion. This arrangement does not quite provide as good a bearing as that shown in FIG. **14***b*, but it does also provide a relatively large display area for letters to be carried on the ring **129**. Also, rather than the U-shaped cores of the electromagnetic devices being permanent magnets along their entire length, they could also have a permanently magnetized portion anywhere along their length. Moreover, the domains could be magnetized permanently and the core pieces could then be merely of a magnetic material, but not permanently magnetized. Another possible modification would be to provide each ring with one or more magnetic domains clustered closely at one portion of the ring. Electromagnetic devices would be distributed along the periphery of the ring to be pulsed in succession to drive the ring.

Nor are the possible variations in driving means limited to those operating on electromagnetic principles. The drive system may also be based on electrostatic, fluidic, or even mechanical principles, although the latter would be undesirable in most cases.

An alternative configuration for the ring support arrangement of FIG. **5** is illustrated in FIG. **15**, with corresponding parts having the same numbers, but with the suffix "a" added. The essential difference between the two configurations is that in the arrangement of FIG. **15** the total contact surface between the ring **19***a* and the bearing **63***a* is much less than in the FIG. **5** device. This is achieved by providing a plurality of projections **135** which extend from the body of the bearing to contact the ring over only a fraction of its total surface. Additional projections **137** and **139** extend toward the ring **19***a* from the lens **51***a* and the top of the ring retainer block **49***a*, respectively. Together, the projections **135**, **137**, and **139** serve to slideably support the ring **19***a* for rotation with a minimum of friction, particularly starting friction, while restricting its movement in every other direction. The bearing **63***a* may be impregnated with a lubricant, with the total contact surfaces of its projections **135** being sufficiently small in relation to the weight of the ring **19***a* to cause the lubricant to be secreted from the bearing due to the contact pressure exerted upon its projections **135** by the ring. With or without such lubrication, the starting friction between the bearing **63**a and the ring **19***a* will diminish with increasing contact pressure, particularly when both of them are made of plastic.

A possible problem with a rotating ring display of the type disclosed herein is that the rings may slip if the display is subjected to extremely large rotative acceleration forces. This may occur, for example, when the display is part of a watch worn by a person engaged in vigorous movements such as serving at tennis, or hammering a nail. Where this is a problem, it may be solved in two ways. First, those electromagnetic devices which drive rings whose positions are critical, such as the date, hour, and minute rings, may be provided with stronger holding magnets than the devices associated with the second ring, whose position is not critical. The advantage of this arrangement is that the inherently large driving power necessary for the second hand can be minimized at the expense of holding stability, which for the second hand is really not a crucial requirement. On the other hand, the holding power for the other rings, whose positions are critical but whose power dissipations are inherently low, can be raised with a relatively small expenditure of power. In other words, power dissipation is allocated unequally among the rings for maximum efficiency.

A second solution to ring slippage is to sense the signals which are induced during ring slippage in the electromagnetic driving means associated with each ring by the magnetic domains upon the ring, since these signals are representative of the direction and extent of ring slippage. Such signals are best sensed during the intervals which occur between the application of driving pulses to the electromagnetic driving means. By means of additional electronic circuits included with the drive circuitry, the slippage information can be processed and driving pulses can be generated, preferably in between regular driving pulses, and applied to those same electromagnetic driving means, so as to compensate for the detected slippage. An important advantage of this method is that the same electronic driving means and the same interconnections between them and the drive circuitry serve both to drive the rings and to detect their change of position.

It may thus be seen that the present invention provides a display device in the form of rotating rings which is much more suitable for use in electronic watches than anything presently available. The display device of the present invention makes possible a watch which is completely sealed, which requires little power since its rings are maintained in their rest positions by permanent magnets, and whose rings may be set, as well as advanced, independently or in combination, without any mechanical devices and at various rates for convenience. And yet this has been achieved without any comprise in legibility of the display. Indeed, the display made according to the present invention can be made to be much easier to read than present watches having hands, since each of the rotating display rings may be arranged to show their indicia through display windows singly, so that even a child can read them at a glance. Moreover, not only can a watch incorporating the display device of the present invention be made to consume less power and be read more easily and be more resistant to environmental hazards than presently available watches, but such a watch can also be produced at less expense, due to the ease with which the rotating rings can be assembled into their casings, which have concentric grooves or annuli for receiving them.

I claim:

1. An electronic watch comprising:

a. a plurality of indicia-bearing rings of different diameters;

b. a sealed casing for supporting said rings therein in an independently rotatable concentric relationship;

c. means for generating a pulse train having a precisely predetermined pulse repetition frequency; and

d. means responsive to said pulse train for driving said rings at different rates, said means being physically separate from, but operatively coupled to, all of said rings.

2. An electronic watch in accordance with claim 1 and characterized further in that said casing includes a plurality of sealed annular chambers, each of which contains a different one of said rings.

3. An electronic watch in accordance with claim 1 and characterized further in that each of said rings carries a plurality of spaced-apart magnetic domains, and said means for driving includes at least two electromagnetic means adjacent said rings.

4. An electronic watch in accordance with claim 2 and characterized further in that said casing includes at least two pairs of slots straddling each of said annuli, said rings each include a plurality of equispaced magnetic domains, and said means for driving includes at least two electromagnetic means magnetically coupled to the magnetic domains of said rings, each said electromagnetic means having a U-shaped, permanently magnetized core extending into a respective one of said pairs of slots and having an electric coil wound thereon.

5. An electronic watch in accordance with claim 3 characterized further in that said magnetic domains have a U-shaped cross-section.

6. An electronic watch in accordance with claim 3 and characterized further in that said means for driving includes at least three electromagnetic means for each of said rings and means for deriving from said pulse train three differently phased pulse trains, each for energizing a different one of said electromagnetic means.

7. An electronic watch in accordance with claim 3 and characterized further in that said means for driving includes means for deriving from said pulse train two differently phased pulse trains, each for energizing a different one of said electromagnetic means.

8. An electronic watch in accordance with claim 1 and characterized further in that each of said rings includes a plurality of magnetic domains.

9. An electronic watch in accordance with claim 8 and characterized further in that said magnetic domains have a U-shaped cross-section.

10. An electronic watch in accordance with claim 2 and characterized further in that said casing includes means for selectively driving less than all of said rings in order to set them, said means being operable to drive said rings at a first rate in response to said means being actuated up to a given length of time and at a second rate in response to a longer actuation of said means.

11. An electronic watch comprising

a. first and second flat casings, the second casing being stacked on the first and having a top wall which is at least partially transparent;

b. a plurality of concentric, individually sealed annular chambers in said second casing, each of said annular chambers containing a freely rotatable ring having a plurality of magnetic domains thereon and carrying indicia visible through said top wall;

c. a set of at least two electromagnetic means anchored in said first casing for each of said rings, each said electromagnetic means having a permanent magnet extending into said second casing and magnetically coupling the magnetic domains of a respective one of said rings, and a winding on said magnet, and

d. an electronic drive circuit in said first casing connected to apply driving pulses to each of said windings.

12. An electronic watch in accordance with claim 11 and characterized further in that the magnets coupling the magnetic domains for a given ring are positioned to hold said ring stationary in a plurality of equispaced rest positions, and the windings on said magnets are operative when alternately energized, to advance said rings successively from a given one of its rest positions to the next one of said rest positions.

13. A display for an electronic wristwatch of the type having an electronic time standard circuit, said display comprising

a. a plurality of indicia-bearing rings of different diameters, each carrying a plurality of magnetic domains thereon,

b. a sealed casing for supporting said rings therein in an independently rotatable concentric relationship, said casing being at least partially transparent to render said indicia visible; and

c. a set of at least two electromagnetic means magnetically coupled to the domains of each of said rings.

14. A display in accordance with claim 13 and characterized further in that said electromagnetic means each includes a permanent magnet for holding one of said rings stationary and a winding on said magnet for counteracting its magnetic field so as to permit said ring to turn.

15. A display for an electronic watch comprising

a. at least one indicia-bearing ring carrying a plurality of magnetic domains,

b. a casing for rotatably supporting said ring therein; and

c. electromagnetic driving means fixed relative to said casing, magnetically coupled to said domains and including

1. a plurality of permanent magnets positioned to hold said ring stationary in a plurality of equispaced rest positions, and

2. a plurality of electric windings coupled to said magnets for causing them, in response to electric current, to exert a forward thrust upon said ring so as to advance it from a given one of its rest positions to its next rest position.

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