Sept. 11, 1962 W. B. POINSOT ET AL 3,053,951

SWITCH ASSEMBLY

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Fig. 1

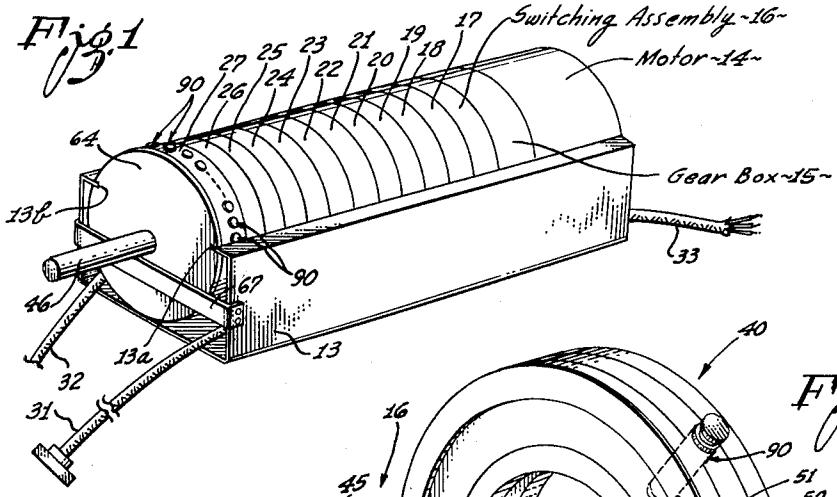


Fig. 2

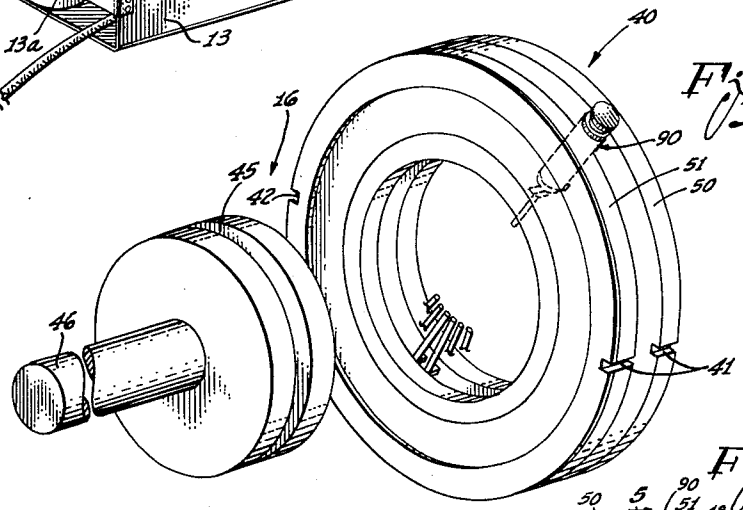


Fig. 3

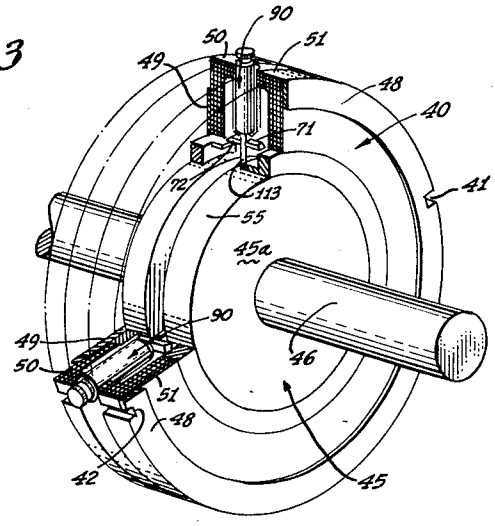
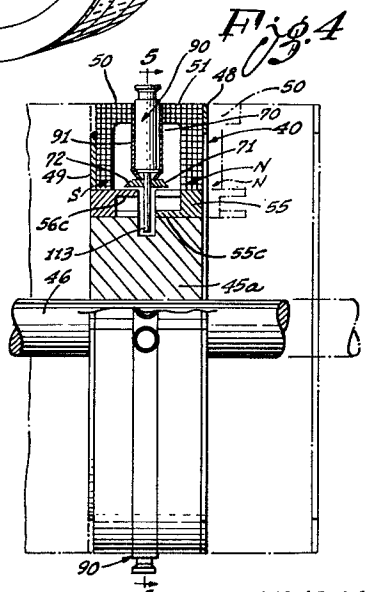


Fig. 4



INVENTORS
William B. Poinsot
Glenn A. Reese

By Smyth & Roston

Attorneys.

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Fig. 5

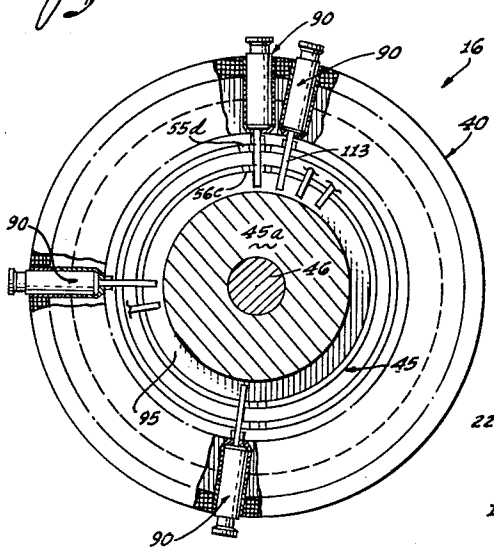


Fig. 6

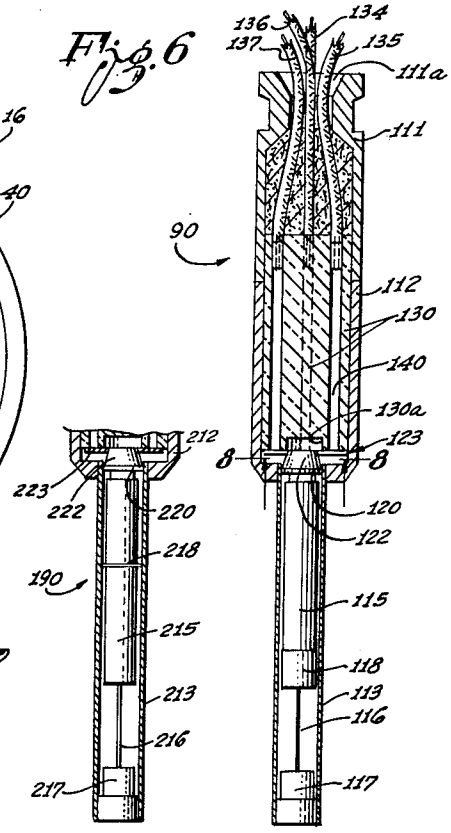


Fig. 7

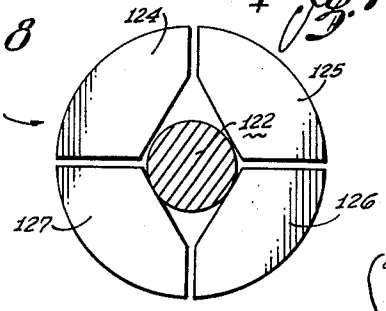


Fig. 8

Fig. 9a

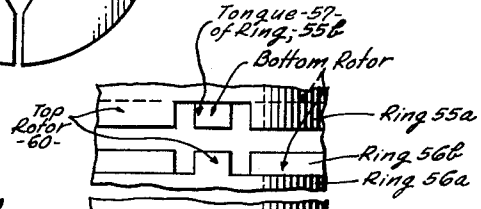


Fig. 9b

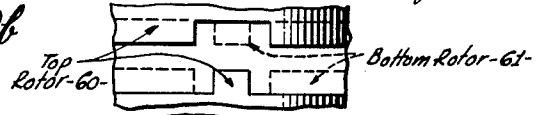
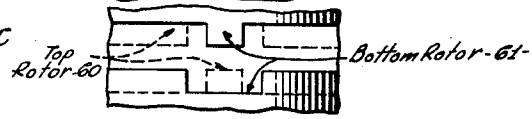


Fig. 9c



INVENTORS:
William B. Poinsot
Glenn A. Reese

By Smyth & Poston

Attorneys.

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SWITCH ASSEMBLY

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Fig. 10a

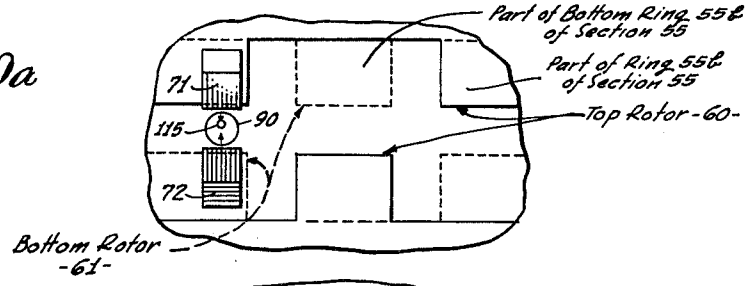


Fig. 10b

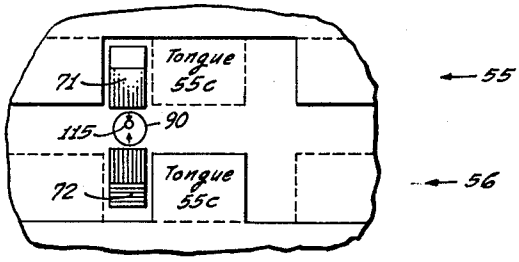


Fig. 10c

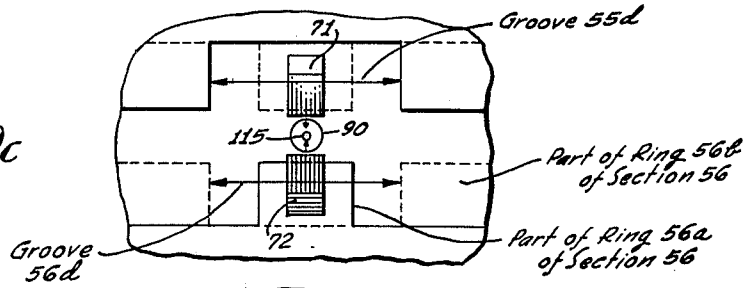


Fig. 10d

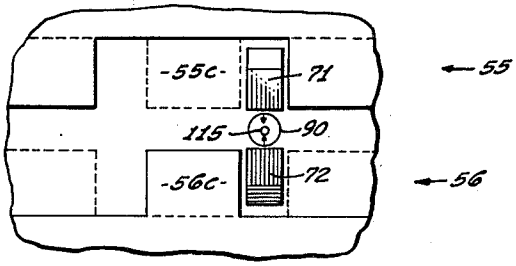
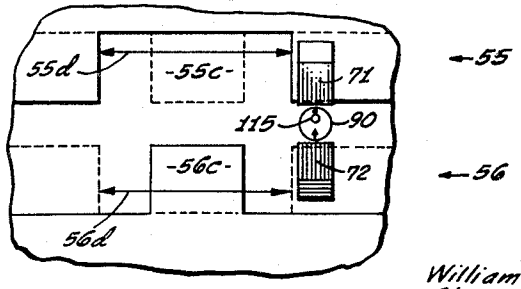


Fig. 10e



INVENTORS:
William B. Poinsot
Glenn A. Reese

By Smyth & Roston

Attorneys.

United States Patent Office 3,053,951 Patented Sept. 11, 1962

3,053,951

SWITCH ASSEMBLY

William B. Poinsot, Sherman Oaks, and Glenn A. Reese, Canoga Park, Calif., assignors to The Magnavox Company, Los Angeles, Calif., a corporation of Delaware

Filed Feb. 8, 1960, Ser. No. 7,389
19 Claims. (Cl. 200—90)

This invention relates to a switch assembly in which a plurality of magnetically operated switches are mounted to extend into an annular air gap and to be swept by flux in the air gap so as to provide successive and periodic operations of the switches. The invention is more particularly directed to an improved switching assembly of this type which is quite small and compact and in which the switches operate at precisely timed intervals.

Switching assemblies which are capable of operating at extremely high switching rates at precisely timed intervals find wide utility in the electronic and electric arts. A number of such switching assemblies are disclosed in co-pending patent applications filed in the name of Glenn A. Reese. These applications include the applications Serial No. 652,968, filed April 15, 1957 (now Patent 2,945,931), Serial No. 656,051, filed April 30, 1957 (now Patent 2,932,699), Serial No. 753,041, filed August 4, 1958, and Serial No. 813,736, filed May 18, 1959. In these co-pending patent applications, a plurality of magnetically operated switches are mounted to extend into an annular air gap. A magnetic flux is produced throughout the annular air gap and slight flux distortions are introduced at predetermined angular positions around the annular air gap. The components which form the annular air gap and the components including magnets which produce the flux in the air gap are mounted on a rotor which is rotated with respect to the magnetically operated switches. The switches are axially mounted in alignment with the longitudinal axis of the rotor at a predetermined distance therefrom. The flux distortions, which are due to the configuration of the rotor, are swept successively past the magnetic switches to provide for this operation. The switches are extremely sensitive and are operated by slight distortions of the flux in the annular air gap.

In each of the above-identified patent applications, the switches are axially aligned, being in alignment with the longitudinal axis of the rotor. In order to provide for the successive operation of the switches, the switches are spaced apart so that such assemblies are bulky when relatively large numbers of switches are utilized. These assemblies are bulky also because the flux pattern, which is rotated adjacent the switches, is developed by magnets in the rotor. The magnets place a limitation as to how small the rotor can be made.

In a copending patent application, filed on even date herewith in the name of Glenn A. Reese, a compact switching assembly of high timing accuracy is provided which occupies less than 25 percent of the volume of the prior switching assemblies. The switches are radially instead of axially disposed with respect to the axis of rotation of the rotor and extend into an annular groove in the rotor. The rotor is made of magnetic material with the magnets utilized to develop the magnetic field through the annular air gap being included as part of the stator. The rotor, without permanent magnets is made quite small. Due to the radial alignment of the switches and the utilization of a magnet free rotor, a more compact assembly is provided and any one of the switches of a stacked assembly arrangement may readily be removed without decoupling the individual assemblies.

In an illustrative embodiment of this invention, a compact radial switch assembly is provided which is an

improvement of the assembly disclosed in the patent application filed on even date herewith. With the switches radially disposed, a small axial movement of the rotor varies the switching interval of each of the plurality of magnetically operated switches by a considerable factor. For example, in the illustrative embodiment, the switches may be operated during successive channels or intervals of 1750 microseconds. An axial movement of the rotor of one hundredth (0.01) of an inch varies the switching interval in one direction or the other by 400 microseconds. Features of this invention relate to the provision of means for maintaining a timing accuracy in the presence of axial movements of the rotor. Illustratively, the switching interval varies by less than 100 microseconds for axial rotor movements of 0.020 inch.

The timing accuracy is maintained utilizing a double rotor assembly having an outer and an inner rotor each including two rings of magnetic material. The two rotors are concentric, with the two rings of each rotor together forming the annular air gap in which the magnetic switches are radially disposed. The annular air gap is formed through both rotors. One ring in each rotor forms at least one tongue and adjacent thereto the other ring forms a groove. The tongue and groove produce flux distortions for operating the switches. Both rotors have the tongues and grooves at the same angular position but the positions of the tongue and groove are reversed being on opposite rings of the two rotors.

The magnetic circuit, which is developed by magnets in the stator, passes through the tongue of one rotor, through the armature of a switch to the tongue of the other rotor. Any axial displacement of the rotors increases the air gap adjacent one tongue and decreases it adjacent the other tongue so that the total reluctance of the magnetic circuit remains the same. Utilizing the double rotor, the operating duration of a switch and its timing position in the operating cycle of the switching assembly are essentially constant. Moreover, the switching interval for operating each switch is at a minimum. The double rotor assembly has an additional advantage in that variations in the construction of the magnetic switches are effectively normalized. The exact alignment of the armature of the switch is not critical.

Further features of this invention pertain to the provision of a pair of steel segments adjacent each of the magnetic switches to effectively pulse the adjacent switch with a steep wave front pulse responsive to distortions of the flux in the annular air gap. The shape of the wave front is independent of the axial position of the rotor. The steel segments, in this manner, assist the double rotor in maintaining the timing accuracy with axial displacements of the rotor.

Still further features of this invention pertain to provision of grooves in one ring of each rotor which are wider than the tongues in the other ring of each rotor. The steel segments move fully adjacent a groove before coming adjacent the associated tongue. In this manner, the flux through one ring of a rotor fully disperses before the flux from the other ring is introduced to the segments.

The utilization of a double rotor provides for forces at the opposite ends of the armature in the magnetic switches as the tongues and grooves rotate adjacent the armatures. Further features of this invention relate to the utilization of magnetic switches having armatures which are pivoted at their centers so that the forces at the opposite ends of the armature are both effective in facilitating its rapid movement.

Further advantages and features of this invention will become apparent upon consideration of the following description when read in conjunction with the drawing, wherein:

FIGURE 1 is a perspective view of a bank of switching

assemblies of this invention and of a motor and gear box utilized to drive the switching assemblies;

FIGURE 2 is an exploded perspective view of the stator and rotor utilized in the switching assembly of this invention;

FIGURE 3 is a partially sectionalized perspective view of the switching assembly of this invention with a portion of the stator and rotor removed;

FIGURE 4 is a partial sectional view of the switching assembly of this invention in a plane perpendicular to the longitudinal axis of the rotor and stator of the switching assembly of this invention;

FIGURE 5 is a sectional view of the switching assembly of this invention taken along lines 5—5 in FIGURE 4 illustrating the spacing of the magnetic switches;

FIGURE 6 is a sectional view through one of the magnetic switches utilized in the switching assembly of this invention;

FIGURE 7 is a sectional view of a portion of another embodiment of a magnetic switch which is utilized in the switching assembly of this invention;

FIGURE 8 is a sectional view taken along lines 8—8 of FIGURE 6 illustrating the relationship of the armature contact and stationary segment contacts of the magnetic switch utilized in the assembly of this invention;

FIGURES 9*a*, 9*b* and 9*c* are schematic representations of the air gap formed by the double rotor of the switching assembly of this invention, wherein:

FIGURE 9*a* is a top view of both rotors;

FIGURE 9*b* is a top view of the top rotor with the bottom rotor shown in dash lines; and

FIGURE 9*c* is a top view of the bottom rotor with the top rotor shown in dash lines; and

FIGURES 10*a* through 10*e* are schematic representations of the air gap formed in the double rotor with the lower rotor being shown by dash lines. These views illustrate the manner in which the movable armature contact in the magnetic switches is transferred between pairs of fixed contacts, and also the timing control of the armature contact by the double rotor. Further, these views illustrate the axial position of the segments positioned on opposite sides of each magnetic switch with respect to the grooves and tongues in the rotor.

Referring first to FIGURE 1, a number of switching assemblies 16 through 27 are positioned side by side and supported by a chassis 13 which may be made of cast metal. Two flanges 13*a* and 13*b* on the sides of the chassis 13 engage slots 41 and 42, shown particularly in FIGURES 2 and 3, in each of the switching assemblies 16 through 27. The switching assemblies 16 through 27 may be operated in synchronism by a motor 14 which is coupled to the switching assemblies 16 through 27 by a gear box 15. Two cables 31 and 32 provide for electrical connections to the switching assemblies 16 through 27 and a cable 33 provides an electrical connection to the motor 14. The bank of switching assemblies 16 through 27, the motor 14 and the gear box 15 may together have a weight of 32 pounds and have overall dimensions of 5 by 6 by 15 inches.

The switching assemblies 16 through 27 may readily be removed from the bank or stack of assemblies by unscrewing a locking plate 67 which holds a circular plate 64 on a common shaft 46, and by sliding the assemblies along the flanges 13*a* and 13*b* of the chassis 13. As indicated above, each of the assemblies 16 through 27 may be of identical construction and the switching assembly 16 shown in FIGURES 2 through 5 is illustrative. As shown in FIGURES 2 through 5, the switching assembly 16 includes a stator 40 which is supported by means of the grooves 41 and 42 on the flanges 13*a* and 13*b* of the chassis 13, and a rotor 45 which is positioned concentrically in the stator 40. The common shaft 46 extends through the rotor 45 and means not shown is provided for attaching the rotor 45 to the shaft 46 so that they rotate together. The attaching means may be in the form of a key, not shown, which must be removed in order to slide the rotor 45 off the common shaft 46. When the switching assemblies 16 through 27 are stacked on the chassis 13, the common shaft 46 extends through the rotor 45 of each of the assemblies 16 through 27. In effect, therefore, the rotors 45 of each of the switching assemblies 16 through 27 are mechanically connected so that they all rotate as a unit.

The rotor 40 includes a number of magnetic switches 90 which are radially aligned about the rotor 40. In the illustrative embodiment of this invention, there are 30 switches 90 in each of the switching assemblies 16 through 27. With 12 assemblies 16 through 27 and 30 magnetic switches 90 for each assembly, there are 12 times 30 or 360 switches included in the stacked arrangement depicted in FIGURE 1. As illustrated in FIGURES 3 and 4, the thirty switches 90 of the assembly 16 are positioned between two permanent magnets 50 and 51. The magnet 50 is magnetized in one direction and the magnet 51 is magnetized in the opposite direction. The internal portion of the magnet 50 adjacent to the rotor 40 may function as a south pole, and the internal portion of the magnet 51 adjacent the rotor 40 may function as a north pole.

A ring 48, which may be made of magnetic material such as steel, is affixed to the side of the magnet 51, and a ring 49, which is smaller than the ring 48 is affixed to the magnet 51. The ring 49 may also be made of magnetic material. The dimensions of the two rings 48 and 49 are such that when the assemblies 16 through 27 are stacked, the ring 48 of one assembly fits over the ring 49 of the adjacent assembly. The minimum diameter of the ring 48 is slightly larger than the maximum diameter of the ring 49.

The magnets 50 and 51 of adjacent assemblies are reversed so that the similarly polarized magnets in adjacent assemblies are positioned adjacent each other. More specifically, the lower portion of the magnet 50 of one assembly at the left in FIGURE 4 is a north pole and also of the magnet 51 of the adjacent assembly at the right. The reason for reversing the magnets 50 and 51 in adjacent assemblies is to prevent the loss of magnetic flux to the stators 40 of adjacent assemblies instead of providing it to the associated rotor 45 in the same assembly. If the magnets are not reversed in this magnet, some of the flux from the north pole of the magnet 51 in the assembly 10 would pass through the ring 49 of the adjacent assembly 17 to the south pole of its magnet 50. If a substantial non-magnetic gap is provided between the stators 40 of adjacent assemblies the magnets 50 and 51 in adjacent assemblies do not have to be reversed.

Between the two magnets 50 and 51 of the stator 40 are positioned a number of cylindrical upper casing sections 70 which may be made of magnetic material, such as steel. Each of the sections 70 encloses part of one of the magnetic switches 90. Each of the magnetic switches 90 is supported in the casing section 70 and also by the lower casing section 91 which is made of non-magnetic material, such as aluminum. The portion of the section 91 adjacent to the rotor 45 is tapered and the switch 90 is correspondingly tapered to fit snugly therein. The two casings 70 and 91 together form a cylindrical enclosure for the upper portion of the magnetic switch 90. The section 70 which is made of magnetic material forms a magnetic return path between the magnets 50 and 51. The section 91 is non-magnetic to avoid shunting any magnetic flux in the lower portion of the switch 90 to the magnetic return path at the section 91. The magnetic circuits through the stator 40 are hereinafter described in detail after the various components in the rotor 45 are described.

The various components of the stator 40 including, the magnets 50 and 51, the rings 48 and 49, the pairs of sections 70 and 91 and a number of pairs of magnetic

segments 71 and 72, which are hereinafter described, are all glued together utilizing illustratively an epoxy resin. The arrangement forms a highly compact and rigid structure. The switches 90, which are held in place by the non-magnetic sections 91 and the magnetic sections 70, may readily be removed from the assembly 16 even when it is in the stacked arrangement illustrated in FIGURE 1. It is therefore unnecessary to decouple the assemblies 16 through 27 in order to remove any of the switches 90 from any of the assemblies 16 through 27.

Each of the magnetic switches 90, as is hereinafter described in detail, includes a lower portion or casing 113 and an upper portion or casing 112 (FIGURE 6) which is somewhat larger than the casing 113 and tapers slightly towards it. Each of the lower casings 113 of the magnetic switches 90 extends into an annular air gap 95 formed in the rotor 45. The annular air gap 95 is formed between two ring members 55 and 56 which are made of a magnetic material, such as steel. The members 55 and 56 are supported by a central portion 45*a* of the rotor 45 which is made of a non-magnetic material, such as aluminum. The two ring members 55 and 56 are continuous about the central portion 45*a* but provide as is hereinafter described for some discontinuity. As the rotor 45 rotates, the successive portions of the two ring members 55 and 56 pass along opposite sides of the lower casings 113 of the magnetic switches 90.

The two magnets 50 and 51 in the stator 40 generate magnetic fields through the members 55 and 56 which control the operation of the switches 90 as the rotor 45 rotates. The two ring members 55 and 56 are each effectively double rings having an upper ring and a lower ring which are contiguous and also concentric with each other. The member 55 has an upper ring 55*a* and a lower ring 55*b*, as shown in FIGURES 9*a* through 9*c*, and 10*a* through 10*e*, and the member 56 has an upper ring 56*a* and a lower ring 56*b*. The lower casing 113 of the switch 90 extends into the gap formed by the double ring arrangement of the members 55 and 56. More specifically, the lower casing 113 extends between the two spaced apart rings 55*a* and 56*a* which have similar diameters and also between the two spaced apart rings 55*b* and 56*b*. The two rings 55*b* and 56*b* have similar diameters which are of course smaller than the diameters of the rings 55*a* and 56*b*.

The two upper rings 55*a* and 56*a* effectively form an upper or top rotor 60 and the two rings 55*b* and 56*b* form a bottom rotor 61. The functional arrangement formed by the two ring members 55 and 56, accordingly, is that of a double rotor with each providing for different flux distortions in the magnetic circuit developed by the two magnets 50 and 51. The flux distortion introduced by the two ring members 55 and 56 are somewhat different due to their different shapes which are hereinafter described in detail.

Though a number of reference designations have been mentioned relating to the magnetic components of the rotor 45, there are actually only two magnetic members and they are the two bands or ring sections 55 and 56. The rotor shaft 46 of course may also be made of magnetic material if so desired, because it is separated by the non-magnetic portion 45*a* from the magnetic sections 55 and 56. The various parts and combination of parts of the sections 55 and 56 have been given reference designations to facilitate their ready identification and thereby an understanding of the operation of the rotor 45.

The upper ring 56*a* is cut back from the annular air gap 95 whereas the lower rings 56*b* has a protruding annular flange extending towards the annular air gap 95. In FIGURE 4, this relationship appears reversed but the section depicted in FIGURE 4 is through the grooves and tongues of the double rotor arrangement. These grooves (55*d* and 56*d*) and tongues (55*c* and 56*c*) are hereinafter described. The shape of the double ring sections 55 is opposite to that of the double ring sections 56 with the upper ring 55*a* having a protruding annular flange extending towards the air gap 95 and the lower ring 55*b* being cut back from the air gap 95. Because of this symmetrical construction, the switches 90 may be centrally positioned in the air gap 95 at equal distances from the two sections 55 and 56.

The upper surface of the ring 55*a* extends adjacent the steel segments 71 which were briefly mentioned above. Each of the segments 71 is one of a pair of segments 71 and 72 positioned at opposite sides of the switches 90 and bridging the gap between the casings 113 and the sides of the ring sections 55 and 56 forming the air gap 95. The segments 71 and 72 which are made of conductive material such as steel, function to maintain the reluctance of the magnetic circuits through the stator 40 and rotor 45 with variations in the axial position of the rotor 45. The function of the segments 71 and 72 is further hereinafter described.

Due to the fact that the magnets 50 and 51 are supported in the stator 40, the flux pattern developed thereby is stationary. The two ring members 55 and 56, which are positioned in the two magnetic circuits developed by the magnets 51 and 50, however, vary the flux paths as they rotate. The upper ring 56*a* of the member 56 of the rotor 45 includes one or more tongues 56*c* (FIGURES 10*a*–10*c*) which extend along the steel segments 72 and towards the annular air gap 95, and the ring 55*a* of the member 55 includes one or more grooves 55*d* which are axially aligned with the tongues 56*c* to provide an air gap to the steel segments 71. The contour of the annular air gap 95 is varied due to the presence of the tongue 56*c* and the groove 55*d* in the top rotor 60.

The bottom rotor 61 has an opposite configuration. The ring 56*b* has a groove 56*d* directly under the tongue 56*c* of the ring 56*a*, and the ring 55*b* has a tongue 55*c* directly under the groove 55*d* of the ring 55*a*. The circumferential width of the grooves 56*d* and 55*d* may be similar to other and larger than the circumferential widths of the tongues 55*c* and 56*c*. The grooves 55*d* and 56*d* may illustratively be twice times as wide as the tongues 55*c* and 56*c*. FIGURES 9*a* through 9*c* illustrate these relationships with FIGURE 9*a* showing both rotors 60 and 61, FIGURE 9*b* showing the top rotor 60 in solid lines, and FIGURE 9*c* showing the bottom rotor 61 in solid lines. The tongues 55*c* and 56*c* may illustratively be 1/16 of an inch wide, and the grooves 55*d* and 56*d* may be 1/8 of an inch wide.

The magnetic circuits through the rotor 45 are fairly complex because of the above-described rotor configuration and because of the presence of the segments 71 and 72. Between the switches 90 about the periphery of the rotor 45 relatively high reluctance paths exist across the air gap 95. The steel segments 71 and 72 are only positioned at the switches 90. Though some magnetic flux is coupled across the air gap 95 between the switches 90 most of it is coupled through the low reluctance paths established by the one or the other of the segments 71 and 72 depending upon the angular position of the rotor 45. When the groove 55*d* and the tongue 56*a* pass adjacent one of the switches 90 the switch 90 is operated due to a change in the flux coupled through the switch 90. Normally the magnetic circuit is from the magnet 51 through the upper ring 55*a*, a steel segment 71, through an armature 115 in the casing 113 of the switch 90, the lower ring 56*b*, and the upper ring 56*a* to the magnet 50. The magnetic circuit is completed through the steel casing 90 back to the magnet 51. Throughout most of the circumference of the rotor 45, the magnetic circuit is through the upper ring 55*a* and the lower ring 56*b*. At the tongue and grooves, however, the magnetic circuit reverses and is through the lower ring 55*b* and the upper ring 56*a*.

The magnetic circuit is not normally through the lower

ring 55*b* and the upper ring 56*a* because they are cut back and provide for relatively large air gaps. The ring 55*b*, being cut off provides for a large gap to the casing 113, and the ring 56*a*, being cut back, provides for a large gap both to the casing 113 and to the segment 72. In this manner normally a low reluctance circuit is provided through the segment 71 and high reluctance circuit is provided through the segment 72. The low reluctance magnetic circuit is interrupted at the grooves 55*d* and 56*d* whereas the higher reluctance circuit through the segments 72 becomes a low reluctance circuit at the tongues 55*c* and 55*d*. The low reluctance path through the tongues 55*c* and 56*c* is from the magnet 51 through the tongue 55*c* of the lower ring 55*b*, the armature 115 of the switch 90, the segment 72, and the tongue 56*c* of the upper ring 56*a* to the magnet 50.

As the rotor 45 rotates in the stator 40, these contour variations define changes in the reluctances of the magnetic circuits to produce variations in the magnetic forces on the armature 115 of the magnetic switches 90. Effectively, therefore, the tongues 55*c* and 56*c* and the grooves 56*d* and 55*d* provide for a rotating flux pattern through the switches 90. A magnetic armature 115 (FIGURE 6), hereinafter described, included in each of the switches 90 is moved as the tongues 55*c* and 56*c* and the grooves 55*d* and 56*d* pass adjacent thereto. The tongues and grooves, in this manner, provide for an operating flux pulse which is rotated successively adjacent the 30 switches 90 in the switching assembly 16.

The effect of the rotation of the rotor 45 is particularly illustrated in FIGURES 10*a* through 10*b*. As shown in these FIGURES, as the rotor 45 of the switching assembly rotates toward the left, the variation in the flux produced by the tongues 55*c* and 56*c* and the grooves 55*d* and 56*d* approaches the switch 90. The switch 90 is stationary being supported in the stator 40. As the tongues 55*c* and 56*c* move adjacent the switch 90, as illustrated in FIGURE 10*c*, the movable armature 115 in the switch 90 is drawn from an upper to a lower fixed contact. The contacts are only functionally depicted as actually the armature contact moves being pairs of contact segments. The segments (124–127) as well as the other components forming the switch 90 is hereinafter described. This operation of the switch 90 is due to the fact that the tongues 55*c* and 56*c* and the grooves 55*d* and 56*d* change the air gaps from the rotor to the armature 115 of the switch 90. When the continued movement of the rotor 45 moves the tongues 55*c* and 56*c* and the grooves 55*d* and 56*d* away from the particular switch 90, the normal magnetic circuit is re-established to return the armature 115 to its original position. As indicated in FIGURE 10*e*, the armature 115 of the switch 90 is moved back to its original position adjacent the upper fixed contact of the switch.

Therefore, each time the tongues 55*c* and 56*c* and the grooves 55*d* and 56*d* are swept adjacent one of the switches 90, the movable contact on the armature of the switch 90 is first drawn out of engagement with one set of fixed contacts and into engagement with another set of fixed contacts. The movable contact is subsequently returned into engagement with the one set of fixed contacts and out of engagement with the other set of fixed contacts. The switch 90 is in this manner pulsed each time the tongues 55*c* and 56*c* and grooves 55*d* and 56*d* pass adjacent thereto. This single-pole, double-throw action of each of the switches 90 is positive in both directions with the movable armature being normally held in engagement with the upper fixed contact and with it being moved by the tongues and grooves to the lower contact and then back again to the upper contact when the tongues and grooves pass.

The width of the grooves 55*d* and 56*d*, as described above and illustrated particularly in FIGURES 10*a* through 10*e*, is twice the width of the tongues 55*c* and 56*c*. The greater groove widths provide for more rapid switch operations. The width of the steel segments 71 and 72 may illustratively be 1/16 of an inch. The relative dimensions of the segments 71 and 72, the grooves 55*d* and 56*d* and the tongues 55*c* and 56*c* are also depicted in FIGURES 10*a* through 10*e*. The dimensions are such that the segment 71 is fully adjacent the groove 55*d* in the upper ring 55 before the segment 72 reaches the tongue 56*c* of the upper ring 56. In this manner the reluctance of the normal magnetic circuit is first increased, and the reluctance of the operative magnetic circuit is decreased to operate the switch 90. The operation is sequential. The normal magnetic circuit as described above, is through the upper ring 55*a* and the lower ring 56*b*, whereas the operative magnetic circuit is through the lower ring 55*b* and the upper ring 56*a*. The magnetic flux path is in effect twisted in a two step operation. In the first step the magnetic intensity in the segment 71 is reduced and in the next step the magnetic intensity in the segment 72 is increased. The force on the armature 115 of the switch 90 due to the flux through the segment 71 is in this manner fully halted before the force due to the flux through the segment 72 is applied.

If the grooves and tongues are of the same width, a small delay occurs due to the necessity of dissipating the flux through the segment 71. The armature 115 remains in its normal position adjacent its upper contacts as the switch 90 moves into the area between the beginning of the groove 55*d* and the beginning of the tongue 56*c*. This operation is functionally depicted in FIGURE 10*b*. Actually the switch 90 is stationary and the grooves 55*d* and 56*d* and the tongues 55*c* and 56*c* move to the left.

In FIGURE 10*c* the tongue 56*c* is adjacent the switch 90 and the armature 115 is in its operative position. There is no counterforce due to flux in the segment 71 because it has been fully dissipated. The transient or switching interval for moving the armature 115 is accordingly quite small, being measured in microseconds. In FIGURE 10*d* the tongue 56*c* has moved away from the switch 90 is that the flux in the segment 72 dissipates. In FIGURE 10*e*, the switch 90 is returned to normal as the extending lip of the ring 55 is now again adjacent the segment 72.

In the particular illustrative embodiment of this invention, there may be two sets of tongues and grooves in the rotor 45 so that each of the switches 90 is operated twice during each revolution of the rotor 45. The rotor 45 may be rotated at a speed of 20 revolutions per second so that each of the switches 90 is operated forty times each second with each switch being operated during an interval of approximately 1,410 microseconds. An interval of 1,750 microseconds is allotted for each channel during which one of the switches 90 is operated. With an operating interval of approximately 1,410 microseconds, the switches 90 are operated during approximately 75% of the 1,750 microsecond interval allotted for each channel and approximately 440 microseconds duration exists between adjacent switch operations. The thirty switches 90 are successively operated during a 52.5 millisecond interval.

Each of the magnetically operated switches 90 may be similar in construction to the switches disclosed in the copending patent application filed on even date herewith by Glenn A. Reese. A switch of this type is illustrated in FIGURE 6.

Referring to FIGURE 6, the magnetic switch 90 has an upper cylindrically-shaped shell 111 and a lower cylindrically-shaped shell 112 together forming a casing for the magnetic switch 90. The two shells 111 and 112 have substantially similar outer and inner diameters and may be of magnetic material such as steel to form a magnetic shield for the components enclosed therein. The shielding function of the shells 111 and 112 is hereinafter described. The two shells 111 and 112 may be welded together to form a single composite cylindrical

casing. At one end of the magnetic shell 112 is affixed the armature casing 113 which is preferably also cylindrical in shape and is adapted to be fitted into the end of the shell 112. The armature casing or extension 113 extends into the annular air gap 95. The armature casing 113 is non-magnetic and may, for example, be of brass to permit magnetic flux through the casing 113 to a hollow armature 115 enclosed thereby. The armature 115 is made of magnetic material such as steel and is preferably cylindrical in shape, being fitted in the armature casing 113. An insulating collar 118 is mounted at one end of the armature 115 for pivotable movement with the armature 115. The insulating collar 118 has an outer diameter which is slightly greater than that of the armature 115 and less than the inner diameter of the armature casing 113.

The armature 115 and the collar 118 are supported on a resilient wire 116 which may be made of steel. The steel wire 116 is supported by a plug 117 which is fitted at one end of the armature casing 113. The plug 117 may be made of magnetic or nonmagnetic material and it may be made of conductive or insulating material. The plug 117 need not be made of insulating material because, as is hereinafter described, the armature 115 does not form part of the electric circuitry through the switch 90. The armature 113 is filled with a viscous oil which forms a cushion for the magnetic armature 115. A thin layer of oil is formed between the insulating collar 118 and the inner surface of the armature casing 113. This layer of oil forms a dynamic pivot for the magnetic armature relative to the armature casing 113 with the collar 118 functioning as the fulcrum. As described above, the armature may be made of steel and the collar 118 may be made of an insulating material. The collar 118 may also be made of a conductive material, as the armature 115 need not be insulated from the armature casing 113 because it does not form a part of the electrical circuits through the switch 90. Though the collar 118 and plug 117 may be made of conductive material, in the specific illustrative embodiment, these components are made of insulating material to reduce the coupling between the casing 113 and the active components in the switch.

At one of its ends, the armature 115 supports the collar 118, and at its other end it supports a contact insulator 120. The contact insulator 120 is a double plug member fitting on one side into the hollow armature 115 and on its other side into an armature contact 122 which is supported thereby. The armature contact 122, which may be made of conductive material such as gold, is circular in cross section, but slight tapered (approximately a 5 degree taper) away from the armature 115. Due to the contact insulator 120, the armature contact 122 is insulated from the armature 115.

The tapered armature contact 122 fits among, and is encircled by four contact segments 124 through 127 of a contact disc 123. The position of the armature contact 122 relative to the four segments 124 through 127 is illustrated particularly in FIGURE 8. In the normal position of the armature 115, the contact 122 is in electrical contact with the two segments 127 and 126 and, when the armature 115 is in its operated condition under the influence of the change in the magnetic field through the casing 113, the contact 122 is in electrical contact with the two segments 124 and 125. The stroke or movement of the contact 122 between the pairs of segments may be quite small, illustratively 0.001 inch. The spacing illustrated in FIGURE 8 is somewhat exaggerated to illustrate that the contact 122 is an electrical contact with only one pair of the four segments 124 through 127. The length of the stroke may be adjusted when the switch is assembled by moving the armature 115 longitudinally in the armature casing 113. Due to the taper of the armature contact 122, its longitudinal movement with respect to the disc 123 varies the spacing between it and the segments 124 through 127.

The minimum distance between the two segments 125 and 127 is substantially equal to the minimum distance between the two segments 124 and 126 so that the armature contact 122 cannot simultaneously electrically contact a pair of opposite segments. For example, the contact 122 can never be simultaneously against the segment 125 and the segment 127 because the distance therebetween is greater than the diameter of the armature contact 122 at its cross-section position in the disc 123. This particular configuration functions as a safety measure to prevent electrically connecting the two functional stationary contacts of the switch 90 which are depicted in FIGURES 10*a* to 10*e*.

The safety measure provided by the particular configuration of a disc 123 and the armature contact 122 avoids establishing an electrical connection between the two stationary contacts at any position of the armature 122, even in the presence of shock or vibration of any magnitude. The two stationary contacts can never be electrically interconnected because the diameter of the armature contact 122 at the disc 123 is smaller than the distance between opposite pairs of the segments of the disc 123.

The contact segments 124 through 127 may be gold plated and may be formed as one continuous disc 123 which is brazed on one end of a ceramic insulator 130. The centrally located diamond shaped opening in the disc 123 is formed by an accurate punch die before the disc 123 is affixed to the insulator 130. After the disc 123 is brazed to the insulator 130, the disc 123 and a portion of the ceramic insulator 130 are cut to form the electrically isolated segments 124 through 127. The ceramic insulator 130 may be cylindrically shaped having a maximum diameter which is substantially the same as the maximum diameter of the disc 123. The ceramic insulator 130 has a small cylindrical opening 130*a* at the end to which the disc 123 is affixed so that the armature contact 122 can be inserted partially therein if necessary. The ceramic insulator 130 fits snugly into the steel shells 111 and 112, which were described above, having a maximum diameter slightly smaller than the inside diameters of the shells 111 and 112. When the ceramic insulator 130 is manufactured, four cylindrical holes 140 are formed through the insulator 130 having axes parallel to the longitudinal axis of the ceramic insulator 130. The end of the ceramic insulator 130 adjacent the disc 123 and the surfaces of the four holes 140 are then metalized by a plating process.

When the disc 123 is cut to form the four segments 124 through 127, the end of the ceramic insulator 130 adjacent thereto is also cut to cut its plated metallic surface. In this manner, the four segments 124 through 127 are insulated from each other having no conductive connection across the metallic surface on the end of the ceramic insulator 130. The four contact segments 124 through 127 are oriented on the ceramic insulator 130 so that an electrically conductive connection is made from each of the segments 124 through 127 to one of the metalized holes 140 in the insulator 130. At the other end of the four metalized holes 140 are inserted, respectively, four wires 134 through 137 which provide for electrical connections to the magnetic switch 90. The four wires 134 through 137 extend through an opening 111*a* at the end of the steel shell 111. In this manner, four electrical connections are provided respectively through the four wires 134 through 137, the four metalized surface holes 140 to the four segments 124 through 127 of the contact disc 123.

The acute angle formed by the internal surface of either pair of two adjacent segments may be between 55 degrees and 60 degrees. The particular angle is selected to reduce any bounce of the armature contact 122. By making the angle acute, a slight skid is developed by the arma-

ture contact 122 as it wedges between the two adjacent internal surfaces. If the acute angle is made larger, the contact 122 hits the segment surfaces with a smaller skidding effect so that any tendency to bounce is increased. The more closely is the contacted segment surface aligned to be perpendicular to the direction of motion of the contact 122, the greater the bounce. Bounce is harmful because of the noise it introduces and because the timing of the switch 90 becomes less accurate. By providing for an acute angle between the internal surfaces of the segments 124 and 125, the contact 122 wedges therebetween as it is moved on the armature 115 so that any tendency to bounce is resisted.

In order to maintain the timing accuracy of the switch, there is a practical lower limit to the size of the acute angle formed by the adjacent internal surfaces of the segment pairs. As the acute angle is made smaller, the tolerances for the contact swing become greater because it is more difficult to predict the exact point on the internal surface which will first engage the contact 122. By making the angle more acute, the dimension of the internal surface in the direction of the contact swing is greater and a small eccentricity in the contact swing varies the duration of the switching operation by a considerable factor. With a stroke of 0.001 inch gives an illustration above, the switching interval responsive to a change of the magnetic flux through the armature 115 may be approximately 200 microseconds. The more perpendicular are the alignments of the contacted internal surfaces with the direction of the movement of the contact 122, the less variation in the switching interval and, therefore, the more accurate the timing provided by the switch 90. The particular angle which is selected is, therefore, a compromise to both reduce bounce and maintain small tolerances in the timing of the switch 90.

Noise pulses are not readily introduced by capacitive or electrical coupling to the armature 115 because it is electrically insulated from the electrical circuits through the switch 90. The contact insulator 120 prevents any electrical disturbances introduced to the armature 115 either by capacitive coupling with the casing 113 or by electrical contact therewith from being introduced to the segments 124 through 127 of the contact disc 123. With the armature 115 isolated in this manner from the electrical circuitry, a noise level illustratively as small as 10 microvolts is present. The 10 microvolt illustrative noise level represents the total noise level due to all factors including due to bounce and stray capacity. Signals, for example, as low as 20 microvolts may accordingly be switched by the switch 90 and readily separated from the noise.

In the switch 90 illustrated in FIGURE 6 and described above, the armature 115 is pivoted at the collar. FIGURE 7 depicts another embodiment of a magnetic switch, which embodiment is particularly suitable for use as part of the switching assembly 16. Referring now to FIGURE 7, a switch 190 is shown which is similar to the switch 90 shown in FIGURE 6. The various similar components have similar reference designations with the addition of 100. The armature 115 in FIGURE 6 has a corresponding armature 215 in FIGURE 7. The armature 115 is supported on a wire 216 in the lower casing 213. The armature contact 222 is movable between the segments of the disc 223. The operation of the switch 190 is exactly the same as that of the switch 90 except that the armature is pivoted at its center instead of at its lower end.

The armature 215 is pivoted on a ring 218 supported by the lower casing 213. The central pivoting operation is particularly suited to the double rotor construction because as illustrated in FIGURE 4 and described above, the operative magnetic circuit is through the tongue 55c of the lower ring 55b, through the armature to the segment 72 and to the tongue 56c of the upper ring 56a. When the tongues 55c and 56c come adjacent the casing 213, the lower end of the armature 215 is pulled towards the tongue 55c and the upper end of the armature 215 is pulled towards the tongue 56c. The forces are applied in this manner at the ends of the armature 215. By pivotally balancing the armature 215 at its center these forces are more effective to move the armature 215 quickly to its operative position. Moreover as is hereinafter described, centrally balancing the armature assists in maintaining the timing accuracy of the switch with variations in the axial position of the rotor 45.

In the rest of the description of the operation of the assembly and in the preceding description, each reference to a switch 90 is also intended to refer to the switch 190 as either can be used in the assembly 16.

Any displacement of the rotor 40 longitudinally along its axis of rotation tends to vary the timing of the operation of the switches 90. Both the double rotor construction and the steel segments 71 and 72 maintain the timing accuracy with axial movements of the rotor 45. For example, in the absence of a double rotor construction and the segments 71 and 72, one 10,000ths of an inch axial movement of the rotor 45 provides for a variation of plus or minus 400 microseconds for a 1750 microsecond channel. As indicated above, the switches 90 are operated successively during the 1,750 microsecond intervals. A variation of plus or minus 400 microseconds provides for a considerable error in the operating duration of the switches 90. The double rotor construction and the segments 71 and 72 reduce this error considerably and in fact greater axial movements, for example as large as 0.0250 inch produce negligible timing variations. When the double rotor, and the segments 71 and 72 are utilized all timing aspects of the switch assembly operation remain substantially constant with axial movement of the rotor 45. For example, the switching interval, and the operating duration of each of the switches 90 is substantially constant.

The steel segments 71 and 72, which are positioned on opposite sides of each of the switches 90, reduce the timing variations because the flux to the switches 90 is actually through one or the other of the steel segments 71 and 72 instead of directly only from the rotor steel rings 55 and 56. As shown particularly in FIGURES 3 and 4, the steel segments 71 and 72 are tapered so that the flux into the segments 71 are directed into the lower tubular casing 113 of the associated switches 90, and the flux from the segment 72 is directed to the tongue 56c. The steel segments 71 and 72 are positioned over the steel rings 55 and 56 of the rotor 45 independent of its axial position. The flux change at the tongue 56c and the groove 55d is effective at the respective instants they pass adjacent the segments 71 and 72. The exact instant the respective fluxes change does not depend upon the exact axial position of the rotor 45, and the magnitude of the flux change also does not depend upon the exact axial position of the rotor 45 because the segments 71 and 72 bridge the gap to the switch 90 irrespective of the axial position of the rotor 45.

Though the axial position of the rotor 45 varies the reluctance of the magnetic path from each of the steel rings 55 and 56 directly to the casing 113 of the switch 90, it does not vary the reluctance of the path through either of the segments 71 and 72 to the casing 113 of the switch 90. In effect, due to the low reluctance of the segments 71 and 72, they distribute the flux from the associated rings 55 and 56 and act as pulses for the switch 90. As the rotor 45 rotates, the flux variation due to the tongues and the grooves accordingly energizes the successive pairs of segments 71 and 72 to pulse their associated switches 90. Due to the segments 71 and 72, the timing accuracy is maintained even with small axial movements of the rotor 45.

As indicated above, the timing accuracy is maintained in the presence of axial rotor movement because of the double rotor construction as well as because of the pres-

ence of the steel segments **71** and **72**. The operative magnetic circuit, which is depicted in FIG. 4, is through the lower ring **55***b*, an air gap to the armature **115** in the casing **113**, through the armature **115** and to the steel segment **72** to the upper ring **56***a*. Due to the proximity of the tongue **56***c* in the ring **56***a* to the armature **115**, some magnetix flux passes from the armature **115** across the small air gap to the tongue **56***c*. There are therefore two small air gaps in the operative magnetic circuit: one from the tongue **55***c* to the armature **115**; and the other from the armature **115** to the tongue **56***c*. Any axial movement of the rotor **45** increases one of these air gaps and decreases the other so that the total reluctance of the magnetic circuit remains approximately constant.

The utilization of a double rotor construction with two tongues **55***c* and **56***c* in the operative magnetic circuit and two air gaps, provides for counteracting reluctance changes responsive to an axial variance in the position of the rotor **45**. Because of the double rotor operation and the bridging function of the pairs of segments **71** and **72** the timing of the switches is very accurate.

When the switch **190** (FIGURE 7) is utilized the forces developed at the opposite ends of the armature **215** are both operative in moving the armature **215**. If a centrally pivoted armature **215** is utilized, any axial movement of the rotor **45** which tends to decrease the force at one end of the armature would tend to increase it at the other end so that the total torque on the armature **215** remains constant.

The timing accuracy is maintained even if the armature **115** (or **215**) is next exactly centered in the casing **113** because any variation of its alignments produces counteracting reluctance changes in the operative magnetic circuit. The tolerances of the switch **90** construction may accordingly be less critical when the double rotor construction is utilized without effecting the timing accuracy. Moreover, the switches **90** need not be accurately aligned in the air gap. For example, if positioned even at angles of 15 degrees from accurate alignment, the timing accuracy of the operation is maintained.

Although this application has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. For example, the number of switches **90** may be more or less than 30, and the sets of tongues and grooves may be more or less than 2. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

We claim:

1. A magnetically controlled switching assembly including, means rotatable on a particular axis and having first and second walls spaced to define a continuous annular air gap between the walls, said walls being made of a magnetic material and having contours to define first and second displacements at radially displaced positions in the air gap in at least one position circumferentially along the walls, stationary magnetic means magnetically coupled to said rotatable means for producing a magnetic field in the air gap in accordance with the contours of the walls defining the air gap, switching means transversely disposed with respect to the axis of rotation of said rotatable means and also having two operating conditions, said switching means being disposed relative to the air gap of said rotatable means and responsive to variations in the magnetic field to be actuated from one operating condition to the other, and means coupled to said rotatable means for rotating said rotatable means to move said walls adjacent said switching means to periodically bring said switching means under the influence of the variations in the magnetic field.

2. A magnetically controlled switching assembly including: a rotor rotatable on a particular axis and including first and second walls spaced to define a continuous air gap between the walls and provided with contours in at least one wall to define first and second displacements in said air gap at radially displaced positions in the direction between the walls, magnetic means coupled to said rotor for producing in the air gap a magnetic flux having uniform characteristics at successive positions in the air gap and exhibiting variations in characteristics at the position of displacement and in accordance with such displacement, and at least one switching unit having first and second switch contacts electrically and magnetically isolated from the casing and movable relative to each other and having an armature coupled to a particular one of the switch contacts and in spaced relationship to the other contact and responsive to the variations in the magnetic flux to produce a relative movement of the particular contact into engagement with the other contact, means for supporting the switching unit to extend into the air gap in a direction perpendicular to the axis of rotation of said rotor with the armature disposed in the air gap to respond to the variations in the magnetic flux in the air gap due to the upper and lower displacements of said one wall, and means for rotating said rotor to produce periodic actuations of the switching unit.

3. A switching assembly, including, a rotor rotatable on a particular axis and including a first set of spaced rings of magnetic material defining between the rings a first continuous air gap having contours to define a displacement in the air gap in at least one circumferential position of the rings, the rotor further including a second set of spaced rings radially positioned with respect to said first set and being made of magnetic material and defining therebetween a second continuous air gap continuous with the first continuous air gap, said air gap defined by the rings of said second set having contours to define a displacement in at least one axial position relative to the air gaps defined by rings of said first set; stationary magnetic means disposed relative to said rotor for producing in said air gap a field exhibiting variations at the position of the displacements; switching means extending into said air gap and transversely disposed with respect to the axis of rotation of said rotor, said switching means having first and second operating conditions and being responsive to the variations in said field to be actuated from the first operating condition to the second operating condition; and means coupled to said rotor for rotating said rings to bring said switching means periodically under the influence of the variations in the field.

4. A switching assembly, including, a rotor rotatable on a first particular axis and including a first set of spaced rings of magnetic material defining between the rings a continuous air gap having contours to define a displacement in the air gap in at least one circumferential position of the rings, the rotor further including a second set of spaced rings of magnetic material radially displaced from the rings of said first set, said rings of said second set defining therebetween a continuous air gap continuous with the air gap defined by the rings in said first set, said rings in said second set defining an axial displacement in the air gap therebetween at a circumferential position corresponding to the displacement of the air gap defined by the rings in said first set, the displacement of the air gap defined by the rings in said second set being different than the displacement of the air gap defined by the rings in said first set, stationary magnetic means disposed relative to said rotor for producing in said air gap a field exhibiting variations at the circumferential position of the displacements, switching means extending into said air gap and transversely disposed with respect to the axis of rotation of said rotor, said switching means having first and second operating conditions and being responsive to the variations in said field to be actuated from the first operating condition to the second operating condition, and means coupled to said rotor for rotating said rings to bring said switching means periodically under the influence of the variations in the field.

5. A switching assembly, including, rotary means having a pair of concentric rotors of magnetic material together defining a continuous annular air gap having a pair of radially displaced contours in the air gap at corresponding positions of the two rotors, means magnetically coupled to the pair of rotors for producing in said air gap a field exhibiting variations at the position of the radially displaced contours, switching means extending into said air gap and transversely disposed with respect to the axis of rotation of said rotor, said switching means having first and second operating conditions and being responsive to the variations in said field to be actuated from the first operating condition to the second operating condition; and means coupled to said rotary means for rotating said rotary means to bring said switching means periodically under the influence of the variations in the field.

6. A switching assembly in accordance with claim 5 wherein each of said concentric rotors has a tongue extending into said annular air gap to define the displacements in said annular air gap, said extensions of the two concentric rotors being on opposite axial sides of said annular air gap.

7. A switching assembly, including, a rotor having a first set of two spaced apart rings of magnetic material defining between the two rings a continuous annular air gap, one of said rings having at least one peripheral groove, the other of said two rings having at least one peripheral groove, the other of said two rings having an extension of magnetic material extending into said annular air gap opposite to said groove in said one ring, and a second set of two spaced apart rings of magnetic material defining between them a continuous air gap which is concentric and contiguous with the air gap defined between the two rings of the first set, one of said rings of said second set having at least one peripheral groove, the other of said two rings of said second set having an extension of magnetic material extending into said air gap defined by said second set and opposite to said groove in said one ring of said second set, at least one magnetic switch radially aligned with respect to the axis of rotation of said rotor and extending into said annular air gaps between the two rings of both said first and said second sets, means having properties to produce a magnetic field through the two rings of both said first and said second sets exhibiting variations at their peripheral grooves and extensions, and means coupled to said rotor for rotating said rotor to effectively rotate the variations in magnetic field successively adjacent said radially aligned magnetic switch, said radially aligned magnetic switch having two operating conditions and being responsive to the variations in the magnetic field to be actuated from one condition to the other.

8. A switching assembly in accordance with claim 7 wherein said ring of said one set having a peripheral groove is concentrically positioned with respect to said ring of said second set having the extension of magnetic material so that they are aligned along a radial line from the center of the rotor.

9. A switching assembly in accordance with claim 7 wherein said peripheral grooves in both said first and said second sets have circumferential lengths greater than the circumferential lengths of the extensions in both said first and said second sets.

10. A switching assembly, including, a rotor having a first set of two spaced apart rings of magnetic material defining between the two rings a continuous annular air gap, one of said rings having at least one peripheral groove, the other of said two rings having at least one peripheral groove, the other of said two rings having an extension of magnetic material extending into said annular air gap opposite to said groove in said one ring, and a second set of two spaced apart rings of magnetic material defining between them a continuous air gap which is concentric and contiguous with the air gap defined between the two rings of the first set, one of said rings of said second set having at least one peripheral groove, the other of said two rings of said second set having an extension of magnetic material extending into said air gap defined by said second set and opposite to said groove in said one ring of said second set, at least one magnetic switch radially aligned with respect to the axis of rotation of said rotor and extending into said annular air gaps between the two rings of both said first and said second sets, means having properties to produce a magnetic field through the two rings of both said first and said second sets exhibiting variations at their peripheral grooves and extensions, means coupled to said rotor for rotating said rotor to effectively rotate the variations in the magnetic field successively adjacent said radially aligned magnetic switch, said radially aligned magnetic switch having two operating conditions and being responsive to the variations in the magnetic field to be actuated from one condition to the other, and two members of magnetic material positioned on opposite sides of said magnetic switch and extending respectively adjacent the peripheral surfaces of said two rings of said one set for providing low reluctance paths to said switch whereby the strength of the magnetic field at said switch does not depend upon the exact axial position of said rotor.

11. A switching assembly, including, means rotatable on a particular axis and including first and second walls spaced to define a continuous air gap between the walls and having contours to define displacements in said air gap along one portion of said walls, said displacements being in the form of grooves in the walls and extensions from the walls, with each of said first and said second walls including one groove and one extension radially displaced from the groove and with the groove in each wall being adjacent the extension on the other wall, switching means disposed partially in said air gap and transversely disposed with respect to the axis of rotation of said rotatable means, said switching means having first and second operating conditions and being responsive to the variations in said field to be actuated from the first operating condition to the second operating condition, and means coupled to said rotatable means for producing relative motion between said walls and said switching means to bring said switching means periodically under the influence of the variations in the field in accordance with the movements of said grooves and extensions of said first and said second walls past said switching means.

12. A switching assembly in accordance with claim 11 wherein each of said grooves has a circumferential length greater than the circumferential length of each of said extensions, and wherein said groove of said first wall is at a greater radial distance from the axis of rotation of said rotatable means than is said extension of said first wall, and said groove of said second wall is at a smaller radial distance from the axis of rotation of said rotatable means than is the extension of said second wall.

13. A switching assembly, including, means rotatable on a first particular axis and including first and second walls spaced to define a continuous air gap between the walls and having contours to define displacements in said air gap along one portion of said walls, said displacements being in the form of grooves in the walls and extensions from the walls, with each of said first and said second walls including one groove and one extension radially displaced from the groove with the groove in each wall being adjacent the extension in the other wall, switching means extending said air gap and transversely disposed with respect to the axis of rotation of said rotatable means, said switching means having first and second operating conditions and being responsive to the variations in said field to be actuated from the first operating condition to the second operating con-

dition, means coupled to said rotatable means for producing relative motion between said walls and said switching means to bring said switching means periodically under the influence of the variations in the field in accordance with the movements of the grooves and extensions of said first and said second walls past the switching means, and segment members magnetically coupled to said elongate switching means and positioned at opposite sides of said switching means and spanning said air gap to inhibit axial movements of said rotatable means from affecting the timing accuracy of the switching assembly.

14. A magnetically controlled switching assembly, including, a rotor rotatable on a particular axis and having first and second walls spaced to define a continuous air gap between the walls, said walls being made of a magnetic material and having contours to define first and second axial displacements in the air gap along the walls, the first axial displacement of the first wall and the second axial displacement of the second wall being grooves, and the second axial displacement of the first wall and the first axial displacement of the second wall being tongues extending toward the grooves, stationary magnetic means magnetically coupled to said rotatable means for producing a magnetic field in the air gap having variations in accordance with the disposition of the tongues and grooves in the walls defining the air gap, switching means extending into the air gap and transversely disposed with respect to the axis of rotation of said rotatable means and having first and second operating conditions, said switching means being responsive to variations in the magnetic field to be actuated from one operating condition to the other, and means coupled to said rotatable means for rotating said rotatable means to move said walls adjacent said switching means to bring said switching means under the influence of the variations in the magnetic field.

15. A switching assembly, including a rotor rotatable on a particular axis and including a first set of spaced rings of magnetic material defining between the two rings a continuous annular air gap, one of said rings having at least one peripheral groove, the other of said two rings having a tongue extending into said annular air gap opposite to said groove in said one ring, the rotor also including a second set of spaced rings of magnetic material defining between them a continuous air gap which is continuous with and radially displaced from the air gap defined between the two rings of the first set, one of said rings of said second set having at least one peripheral groove, the other of said two rings of said second set having a tongue extending into said air gap defined by said second set and opposite to said groove in said one ring of said second set, at least one magnetic switch transversely disposed with respect to the axis of rotation of said rotor and extending into said annular air gaps between the rings of both said first and said second sets, means producing magnetic fields through the rings of said first and said second sets and producing variations in the magnetic fields at the peripheral grooves and tongues, and means coupled to said rotor for rotating said rotor to obtain rotary movements of the variations in magnetic field past said magnetic switch, said magnetic switch having first and second operating conditions and being responsive to the variations in the magnetic field to be actuated from the first operating condition to the second operating condition.

16. A switching assembly in accordance with claim 15 wherein the peripheral groove of said ring of said one set is concentrically positioned wtih respect to the tongue on said ring of said second set so that they are aligned along a radial line from the center of the rotor.

17. A switching assembly in accordance with claim 15 wherein said peripheral groove in the ring of each of said first and said second sets has a circumferential length greater than the circumferential length of the tongue in the ring of each of said first and said second sets.

18. A switching assembly in accordance with claim 15 wherein the ring having the peripheral groove in each of the first and second sets is disposed radially at a position corresponding to the ring having the tongue in the other of the first and second sets.

19. A switching assembly, including, a rotor rotatable on a particular axis and including a first set of spaced rings of magnetic material defining between the rings a continuous annular air gap, one of said rings having at least one peripheral groove, the other of said rings having a tongue extending into said annular air gap opposite to said groove in said one ring, the rotor also including a second set of spaced rings of magnetic material defining between them a continuous air gap which is continuous with and radially displaced from the air gap defined between the rings of the first set, one of said rings of said second set having at least one peripheral groove, the other of said rings of said second set having a tongue extending into said air gap defined by said second set and opposite to said groove in said one ring of said second set, at least one magnetic switch disposed transversely with respect to the axis of rotation of said rotor and extending into said annular air gaps between the rings of said first and said second sets, means having properties to produce magnetic fields between the rings of said first and said second sets wherein the magnetic fields exhibit variations at the peripheral grooves and tongues in the rings of the first and second sets, means coupled to said rotor for rotating said rotor to obtain movements in the variations in the magnetic field past said magnetic switch, said magnetic switch having first and second operating conditions and being responsive to the variations in the magnetic field to be actuated from the first operating condition to the second operating condition, and a pair of members of magnetic material positioned on opposite sides of said magnetic switch and extending respectively adjacent the peripheral surfaces of said rings of said one set for providing low reluctance paths to said switch to cause the intensity of the magnetic field at said switch to be independent of variations in the axial position of said rotor.

References Cited in the file of this patent

UNITED STATES PATENTS

2,932,699	Reese	Apr. 12, 1960
2,945,931	Reese	July 19, 1960