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HIGH SPEED STEPPING APPARATUS

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2 Sheets-Sheet 2

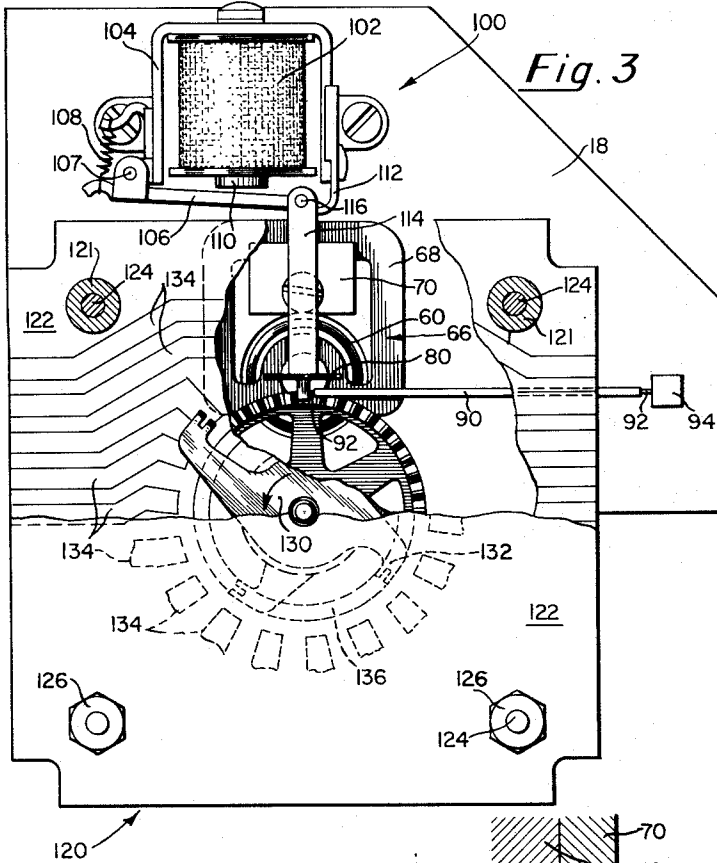


Fig. 3

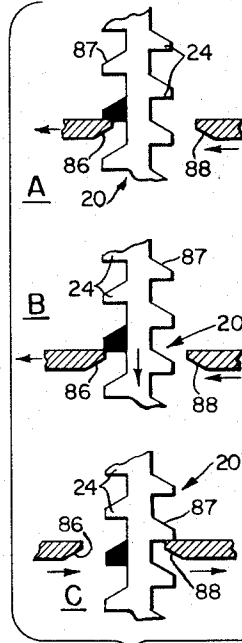


Fig. 4

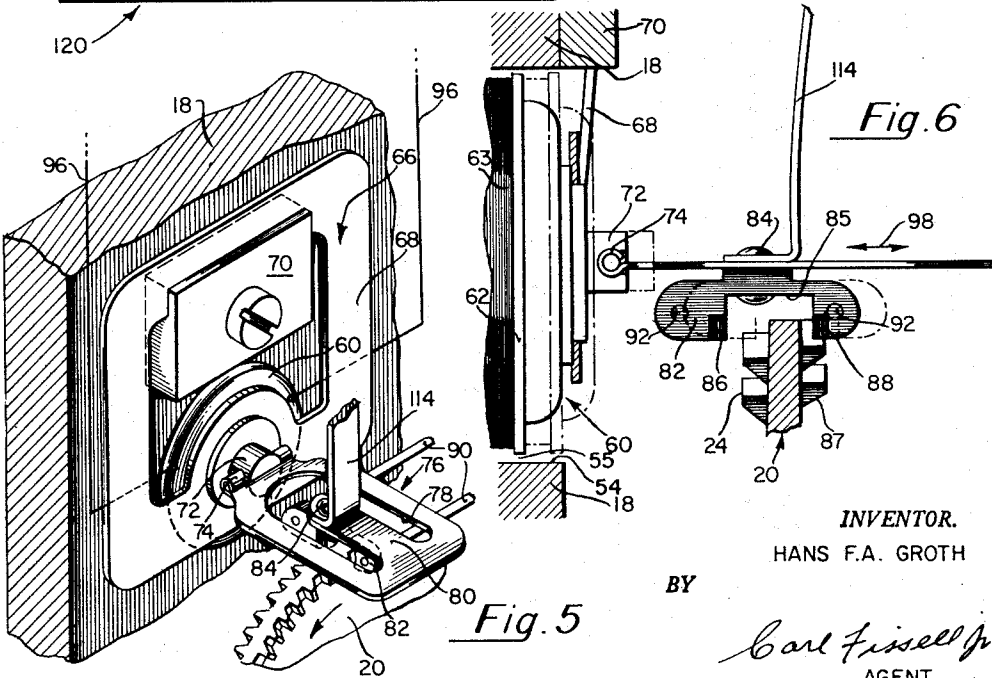


Fig. 5

Fig. 6

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HIGH SPEED STEPPING APPARATUS

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This invention relates to stepping mechanisms, and more particularly, to extremely high speed electrically controlled mechanisms of the step-by-step type which are operable in response to successive electrical actuating impulses.

Prior art stepping mechanisms have certain limitations and disadvantages which have in the past tended to prevent the attainment of relatively high operating speeds. One of the more common problems with known stepping mechanisms is that the relative operating speeds generally are derived for the most part from the actuation of an electromagnet or a solenoid or from the stored energy of a spring which is or may be cocked by such electromechanical components. Since the load determines the size of the spring and of the armature, the more mass there is to be driven the stronger the spring and armature must be for this driving purpose and therefore the larger and more powerful the electromagnet or the solenoid must be to drive or to cock the spring.

Stepping mechanisms of the foregoing type have been relatively large and bulky due to the driving forces involved.

Other problems with known stepping mechanisms include the high mass of the driven parts and the size and mass of the mechanism used to permit the device to advance step-by-step, i.e., escapement arm, pallet, pawls, etc.

In view of the foregoing it is an important object of the present invention to provide a simple efficient and relatively inexpensive stepping mechanism which avoids the foregoing limitations and which attains extremely high operating speeds.

It is another object of the invention to provide an extremely high speed stepping mechanism in which the driving force is independent of the stepping control function of the mechanism.

It is still another object of the invention to provide a step-by-step mechanism the operation of which may be synchronous or asynchronous.

It is still another object of the invention to provide a high speed low inertia stepping mechanism wherein a moving coil actuated escapement mechanism controls a high break away torque and checks a low impact torque when the mechanism is stopped.

In accordance with the above objects and first briefly described herein, the present invention provides a novel extremely high speed stepping mechanism including a rotatable drive shaft subject to a constant unidirectional torque supplied thereto. Rotation of the drive shaft is controlled by a double faced escapement wheel which is releasably, radially engaged by an electromagnetic moving coil actuated latch. The latch is permitted a freedom of movement in a direction parallel to the axis of rotation of said escapement and in a radial direction for purposes of resetting the mechanism to zero. Axial-lateral movement of the latch permits the escapement wheel to rotate an increment at a time under the application of the constant torque.

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In the preferred embodiment of the invention, described in detail hereinafter, the stepping mechanism is operably associated with a commutator type rotary switch apparatus wherein an insulating hub secured to and rotatable with the drive shaft of the stepping mechanism carries at one end thereof a plurality of radially mounted conductive wiper arms which are disposed between a pair of parallel spaced plates. These plates have a plurality of etched circuit members such as slip-rings and parallel busses confronting the wiper arms. The step switch may be caused to move step-by-step continuously and successively over the etched circuit busses in response to applied electrical pulses at extremely high speed. An electromagnetically controlled reset device permits the mechanism to return to a selected starting position for the initiation of another switching operation.

The features of the invention which are believed to be novel are set forth with particularity in the following specification and in the appended claims. The invention itself, however, both as to its organization and operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a side elevational view of the invention partially in section with portions thereof broken away to expose some of the structural features of the invention;

FIG. 2 is a detail view drawn to an enlarged scale of a portion of the control mechanism of the present invention;

FIG. 3 is a front elevational view of the invention with certain portions broken away to expose the escapement wheel and the commutator mechanism employed therewith;

FIG. 4 is a compound view greatly enlarged of a portion of the escapement wheel and latch illustrating the manner in which the wheel escapes a tooth at a time;

FIG. 5 is an isometric view of a portion of the electromagnetic control mechanism of the invention drawn to an enlarged scale to more clearly illustrate the novel structural combination; and

FIG. 6 is an enlarged detail view of the escapement mechanism illustrating two of its operational positions.

Referring now more particularly to the drawings and to the various figures thereof which will be discussed simultaneously, it is seen that the novel high speed stepping mechanism of the present invention includes a plurality of sub-assemblies which are operably interconnected to form a unitary structure. The illustrated embodiment is shown operatively associated with a rotary stepping switch but it is to be understood that the novel step-by-step mechanism herein described and illustrated may find application in other and different environments, and the scope of the invention is thus not to be considered as limited to stepping switches per se. The present inventive concept is equally applicable to any apparatus wherein it is desired to move a machine element rotatively or laterally in discrete timed intervals at extremely high speed under the control of electric pulses.

As shown in FIG. 1, the high speed rotary stepping switch and resetting mechanism of the present invention includes a central or common rotatable shaft 10 concentrically mounted within a spacing sleeve 12, journaled in bearing members 14—14' disposed at opposite ends of the sleeve 12 and press fitted or otherwise mounted

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in wall members 16 and 18. In the preferred embodiment, the members 16 and 18 may be formed of soft iron or other magnetizable material as will be explained later on. The shaft 10 is of sufficient length, as shown, to provide a support for various additional elements which are employed with the present invention and described hereinafter.

Intermediate the ends of shaft 10, adjacent wall member 18 and disposed thereon prior to assembly of the complete apparatus, is an escapement wheel 20 which may be secured to shaft 10 in any well known manner, as by means of a dowel pin 22, so that the escapement wheel is obliged to rotate with the shaft. The escapement wheel, as seen in FIG. 1, is double faced, i.e. each side face of the wheel is provided with a plurality of tooth-like projections 24 formed along the opposite peripheries thereof such as by being stamped, pressed, cut or molded integral with the peripheral web of the wheel. For purposes to be explained presently, the projections 24 on one peripheral edge of the wheel 20 are off-set or displaced angularly with respect to the projections 24 on the opposite peripheral edge of the wheel. The amount or degree of such off-set or displacement is a matter of design, however, in the illustrated embodiment the teeth on opposite sides of the escapement wheel are off-set angularly by one-half the circular pitch of the teeth on one side. In this manner each quadrant of the wheel, as seen in FIG. 3, may be provided with nine teeth or a total of thirty-six teeth for each side of the wheel, seventy-two teeth in all.

For a purpose to be explained hereinafter, the escapement wheel 20 is provided with a relatively long projecting tooth 26, FIGS. 1 and 2, formed in a suitable manner out of the web of the wheel and extending outwardly away from the periphery of the wheel a substantial distance. Projection 26 is adapted to provide a zeroizing abutment or home stop for the escapement wheel 20, and operates to detent the wheel when it is reset, in a manner to be explained presently.

Shaft 10 is adapted to be constantly rotated at a relatively high rate of speed. To this end, a friction coupling or slip clutch 28 is provided in order to couple a constantly rotating input power shaft 30 to shaft 10. Slip clutch 28 may comprise any suitable well known type of slip clutch, however, for purposes of the present description a magnetic hysteresis clutch is illustrated. The clutch includes an input cup-shaped member 32 secured to shaft 30 as by the pin 34, and carries a substantially circular permanent magnet member 36 centrally disposed within the member 32 and forming, together with the upstanding wall 37 thereof, an air gap 38. Magnet 36 which may be press fitted to a hub 39 integral with member 32 may include a number of magnetic polar castellations 40 forming alternate north and south poles in a manner well known in the magnetic clutch art. Output member 42, also cup-shaped, is secured to a collar 43 attached to one end of shaft 10 such that the cylindrical portion 44 of member 42 is rotatable substantially wholly within the air gap 38. In this construction a complete magnetic loop is provided by means of the magnet 36, drive cup 32 and air gap 38 within which the wall 44 of member 42 is rotatable.

It should be apparent from the foregoing that with shaft 30 rotating, a continuous torque is applied to shaft 10, through coupling 28, so that shaft 10 will rotate unless it is restrained by some external force, such for example, as the control mechanism to be described hereinafter.

Disposed between the two frame or wall forming members 16 and 18 is a magnetic structure 46 including a hollow cylindrical permanent magnet 48 having a substantially solid centrally located cylindrical ferrous or other type magnetic core 50. The magnetic structure may be integral with or suitably attached to the wall member 16. The rightward rim portion of magnet 48

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abuts the wall member 18 and is secured thereto, as by welding. The unattached end of the iron core 50 is provided with an enlarged circular portion or pole 52, which may be integral therewith, and which extends into an aperture 54 provided in wall member 18. The clearance between the rim of aperture 54 and the periphery of pole 52 forms an air gap 55. The foregoing construction forms a magnetic circuit including magnet 48, wall member 16, wall member 18 and the air gap 55. The core 50 is hollowed axially longitudinally as by drilling to provide a central open bore 56 therethrough. Back plate 16 is likewise drilled to provide an opening 58 located in registry with bore 56.

A movable cup-shaped coil form or support 60, including parallel spaced apart flanges or rims 62, FIGS. 1, 2 and 6, forming an annular recess therebetween, is provided with a plurality of turns of electrical conductors forming an energizing coil 63 disposed within the recess. The ends of the coil may be brought out along the flexible support member 66, as shown in FIG. 5, for connection to a suitable source of electrical energy, not shown, in well known fashion.

Coil form 60 is movably suspended within the air gap 55 by means of two suspension members or swings 66 on opposite ends thereof, and which, in the present illustrated embodiment, may comprise light weight, resilient, rectangular flex-frames 68, of suitable material, such as metal or plastic, supported in slotted mounting block 70, bolted to respective wall members 16 and 18. The two swings are interconnected by means of a tubular member 64 concentric with and extending through pole 52, by way of the bores 56 and 58. In this manner the coil 63 is provided with a suspension having elastic axial freedom but which is substantially rigid at right angles thereto. The degree of flexibility may be varied as required, by the design and material of the swinging frames 68.

The inner portion 69 of the hub of coil form 60 is drilled to receive the tubular member 64. The hub extension 72 is drilled transversely and the face thereof slotted to receive the mounting hinge 74 of a flat spring member 76, as shown most clearly in FIG. 5. Spring member 76 is provided with a U-cutout 78 providing a flat tang or tab 80 projecting into the opening thus provided.

A yoke-shaped escapement wheel pawl, latch or shuttle, hereinafter referred to as a latch 82 (FIG. 6) of relatively rigid but substantially light weight construction is secured by means of a rivet 84 to the underside of the tab 80 with its principal or longitudinal axis in line with the tab. A thin, light weight and relatively flexible strap 114 is attached to the upper surface of tab 80, the purpose of which will be explained later. Latch 82, notched as at 85, straddles the escape wheel 20 and its sides 86 and 88 are chamfered to match the trailing portions 87 of the escape wheel teeth. The rest or neutral position of latch 82, coil 63 and coil suspension 68 with respect to wheel 20 may be chosen, as shown in FIG. 4A, such that the latch is disposed with each side thereof in the path of its associated set of escape teeth 24. With the application of a current pulse to the coil 63 in the proper direction, as will be explained later on, the latch 82 will move to the left permitting one tooth (the left) to escape as shown in FIG. 4B. The wheel is, however, promptly arrested by the opposite edge 88 of notch 85 engaging an alternate tooth of the escape wheel. FIG. 4C shows the right hand tooth engaged, while the left hand edge 86 of the notch is clear of its tooth. With the current off, the latch will return to its neutral, rest position still restraining the wheel. Pulsing the coil in the opposite direction will cause the latch to shuttle to the right permitting one tooth on the right side to escape and engaging the alternate tooth on the left side. The wheel 20 is thus permitted to step along one half the circular pitch with each pulse reversal. Another mode of operation

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may be obtained wherein the rest position of the latch 82 is either fully to the right or to the left position resulting in the full engagement of the latch with a tooth. In this mode of operation pulsing the coil in the proper direction will allow the wheel to step two teeth in two equal steps per pulse, one step each for "on" and "off," or make and break the applied current.

In a manner to be explained presently the long tooth 26 is adapted to abut the inner edge 86 of latch 80 and in this manner provides a means for detenting the escape wheel in its home position. It should be apparent from the foregoing that by virtue of the notch 85 in the latch 80 each time coil 63 is energized and de-energized the latch will be moved axially of shaft 10 transversely across the teeth of the escapement wheel permitting one tooth at a time to escape as clearly shown in the three views of FIG. 4 allowing the shaft 10 to rotate through an arcuate increment equal to the angular space between teeth 24 on opposite sides of the wheel.

Escapement wheel latch 82 is swingably mounted for movement in a horizontal direction transverse to the direction of movement of wheel 20, FIG. 1, by means of a pair of support or swing members 90—90, FIGS. 2 and 5, which may be of light weight tubular construction. Each support member 90 is provided with a flexible wire-like element 92, FIG. 3, extending away from the opposite ends thereof. One end of each member 90 may be secured to the latch by introducing the wire elements 92 thereof into holes provided in the latch and peening over the ends of the respective wires 92. The opposite end of each swing member is fastened by means of its respective wire 92 in a similar manner to a projection or post 94 extending outwardly away from the wall member 18. By virtue of the foregoing construction the latch is permitted a freedom of movement in a direction parallel to the shaft 10 while being rigidly restrained in a direction longitudinally of each support member 90 as seen in FIG. 3.

Assuming that the output shaft 10 is under a rotative load from input shaft 30 through the coupling 28, it is apparent that without more, the latch 82 will restrain the escapement wheel 20 by abutting a tooth on one or the other side of the escapement wheel, as shown in FIG. 6.

If now an electrical signal in the form of a current pulse, for example, is applied over the conductive leads 96 to the electrical windings of the coil 63, the coil form will be caused to move at extremely high speed in much the same manner as the high frequency movement of the moving voice or voice coil of a radio loud speaker. By alternately reversing the current direction through the coil 63, coil form 60 can be attracted and repelled, back and forth within the air gap thus moving the latch 82, as seen in FIG. 6, from its full line to its dotted line position and vice versa as indicated by the two-headed arrow 98. This voice coil-like movement of the latch 82 permits the escapement wheel 20 to step one projection or tooth at a time as each pulse is applied to the coil 63. Thus it is seen that an extremely high frequency, high speed step-by-step, low inertia, escapement type mechanism is provided in which a source of constant torque is applied to a rotative member which is detented and periodically released in response to the application of controlled electrical signal pulses.

As before mentioned, depending upon whether the electrical current is applied in a clockwise or counterclockwise direction, coil form 60 will be oscillated to the left or the right, as viewed in the drawings. If it is inconvenient in a particular application to provide means for causing the current to be periodically reversed, the construction of FIG. 1 may be modified so that the coil form 60 is biased in one direction only, e.g., by means of the member 66, in which case the electrical current pulses are then applied in a direction such as to move the coil form and thus the latch 82 in an opposite direction to that in which the latch is biased.

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In apparatus such as that described hereinabove, it may be desirable to home or zeroize the mechanism, i.e., restore it to some preselected position. A novel means for performing such zeroizing function is illustrated in FIGS. 1 and 3. Referring particularly to FIG. 3 there is provided a reset mechanism 100 including a relay type electromagnet 102 suspended by means of a substantially U-shaped supporting bracket or frame member 104. Frame member 104 may be suitably mounted to the wall member 18 as by bolts and nuts. The armature or clapper 106 of the electromagnet 102 is pivotally mounted to one side of the frame member 104, as indicated at 107, and is biased by means of a spring 108 away from its pole piece 110 and into engagement with a limit member 112. The latter member being adjustably slidably mounted on the supporting bracket 104.

The elongated semi-rigid yet suitably flexible member or strap 114, earlier referred to herein, is pivotally mounted at one end to the armature 106 as indicated by reference character 116. The opposite depending end of the strap 114 is secured to the tab 80 of the spring leaf 76 by means of the rivet 84. In order to reset the step-by-step mechanism including the escapement wheel 20 to its zero or home position, the electromagnet 102 is energized over the leads 118 from a source of electrical energy, not shown, thereby attracting the armature 106 to its pole piece 110 whereupon the strap 114 lifts spring leaf 76 arcuately, vertically in FIG. 2. This movement of strap 114 is of sufficient extent to draw the latch 82 upwardly out of the path of movement of the tooth-like projections 24 on the escapement wheel, but not out of the path of movement of the high tooth 26. If the escapement wheel 20 is now rotated under the urging of the constant torque through coupling 28, the high tooth 26 will be brought into abutment with latch 82 abruptly stopping the wheel 20 in its zero or home position.

In FIGS. 1 and 3 a commutator type rotary switch structure 120 is shown operatively coupled to the novel stepping mechanism aforedescribed. Attached to the member 18, as by hollow spacers or pedestals 121 of varying extent, are a plurality of thin planar circuit members 122—122, the latter being supported in parallel spaced apart relation on the pedestals 121—121 by means of bolts 124 projecting outwardly away from the member 18 and nuts 126 threaded on the free ends thereof.

The circuits for the members 122—122, which may be fabricated by any of a number of well known ways, such as by printed circuit techniques, are mounted with their respective electrical circuit portions in confronting face to face relation as seen in FIG. 3. It is to be understood that neither the specific circuit resulting from the etching technique used nor the etched circuit construction generally forms any part of the present invention but is used herein solely as an illustration of one form of commutator type switch apparatus which may be employed with the present invention.

Prior to attaching the etched circuit members to the spacing supports 121, shaft 10 is provided with an electrically insulating hub member 128, FIG. 1, secured thereto in a conventional manner as by key and key way, or dowel pin, etc., not shown, for rotation therewith. The hub 128 carries on each opposite side or face thereof an individual electrically conductive double armed commutative wiper member 130. The oppositely extending arms of wiper members 130 are each provided with bifurcated contact members 132 bent outwardly at right angles away from the central portion of the end of each arm so as to be pressed lightly but firmly against the confronting surface of a respective member 122—122.

As seen most clearly in FIG. 3, each etched circuit member 122 may be provided with a plurality of radiating spoke-like conductive busses 134 and an annular conductive buss 136 forming a common electrical connection therefor. The length of the wiper arms 130 are chosen such that one arm of each double armed member is slight-

ly shorter than the other opposite arm and rides on the common buss 136 while the other arm of the same wiper rides successively over each radiating buss 134, as the shaft 10 is rotated thus to successively close different circuits associated therewith.

In the present application there has been described a novel step-by-step mechanism which receives its driving torque from a constantly rotating external source of power. The torque is applied through a yielding coupling to a shaft carrying the apparatus it is desired to control in discrete steps. A moving coil-actuated low inertia shuttle type escapement mechanism provides instantaneous, momentary step-by-step advancement of the shaft and associated apparatus without appreciably affecting the primary driving source, while at the same time permitting extremely high speed stepping operation. It is to be noted that the present invention is, or may be, asynchronous in its operation in that the electrical impulse energy applied to the control elements of the mechanism can occur at any particular rate, random or otherwise, and the mechanism will be stepped in accordance therewith. Finally, the present invention provides a practical novel reset or zeroizing mechanism which may be actuated from any position of the escapement wheel at any desired time.

What is claimed is:

1. High speed stepping apparatus comprising in combination, a pair of parallel spaced apart magnetic wall forming members, one of said members having an aperture therethrough, a rotatable shaft journaled between said wall members, means coupling said shaft to a source of constant torque, a toothed escapement wheel disposed on and rotatable with said shaft, a cylindrical magnetic member disposed between said wall members and including an axially aligned magnetic core, one end of said core extending into said aperture and forming an air gap between said core and the rim of said aperture, an electromagnetic member surrounding the said one end of said core and movable back and forth within said air gap, a latch for said escapement wheel, means operatively interconnecting said latch to said electromagnetic member, and means connecting said electromagnetic means to a source of electrical energy whereby upon energization and de-energization of said electromagnetic means said latch is engaged and disengaged with said escapement wheel thus permitting said wheel to be rotated step-by-step in response to the applied torque.

2. High speed stepping apparatus comprising in combination, a rotatable shaft, means releasably coupling said shaft to a source of constant torque, an escapement wheel rotatable with said shaft, said escapement wheel including a plurality of oppositely disposed off-set peripheral rows of tooth-like projections, a latch movable transversely and alternately into and out of engagement with the peripheral projections on said rows, electromagnetic means for so moving said latch transversely of said wheel whereby said wheel is permitted to step in individual discrete increments in response to said constant torque, stop means on said wheel engageable with said latch, and electromagnetic means operatively connected to said latch for disengaging said latch from said peripheral projections while causing said latch to engage said stop means in a home position as said wheel is rotated whereby said wheel is restrained from rotation.

3. High speed stepping apparatus comprising in combination, a rotatable shaft, a slip clutch coupling said shaft to a source of constant torque, an escapement wheel having peripheral rows of teeth on each face thereof, the teeth on one face being radially off-set with respect to the teeth on the other face, a latch straddling said wheel and operable alternately to engage the teeth in each row to detent said escapement wheel, means to move said latch transversely of the plane of rotation of said wheel to cause said latch to engage and disengage opposite off-set teeth thus permitting said wheel to rotate therepast one

tooth at a time in response to the application of said constant torque, and a resetting mechanism for said apparatus, said mechanism including detenting means carried by said escapement wheel, and electromagnetic means engaging said latch and responsive to the energization of said last means for retracting said latch out of the path of movement of the teeth of said escapement wheel during rotation thereof to a reset position and into engagement with said detenting means when it has reached its reset position.

4. High speed stepping apparatus comprising in combination, a rotatable shaft, an electromagnetic clutch coupling said shaft to a source of constant torque, an escapement wheel disposed on said shaft and rotatable therewith, electromagnetic means having an electrical signal responsive element, and an escapement latch engaged by said signal responsive element and movable in response to movement of said element, said escapement latch including oppositely disposed substantially parallel projecting portions thereon adapted to alternately engage opposite sides of said escapement wheel thus to stop said wheel after predetermined increments of rotation thereof in response to said applied torque each time said electromagnetic means is energized, means to reset said escapement wheel to a home position, said reset means including an electromagnet having a clapper, a member operatively connected to said escapement latch and pivotally mounted to and moved by said clapper, and means on said escapement wheel adapted to be releasably engaged and disengaged by said reset means in response to the energization and de-energization of said electromagnet thereby to reset said escapement wheel.

5. High speed step-by-step switching apparatus comprising, in combination, a rotatable shaft, a magnetic hysteresis clutch coupling said shaft to a source of constant torque for conjoint rotation, an escapement wheel fixed to and rotatable with said shaft in response to the application of said torque to said clutch, said escapement wheel having integral oppositely disposed peripheral rows of tooth-like projections thereon, said wheel further including a reset projection of greater extent than said tooth-like projections, a magnetic member provided with an axial bore adapted to receive a movable element therethrough, a movable element receivable through said bore, a cup-shaped coil carrying member including a coil thereon receivable over one end of said magnet and secured to said movable element, suspension means offering low resistance to axial movement of said element and being rigid in all other directions, attached at opposite ends of said element, a latch member coupled to and movable with said movable element releasably restraining said escapement wheel, and means to withdraw said latch from restraining engagement with the peripheral projections on said escapement wheel and into the path of movement of said reset projection thereby permitting said escapement wheel to be rotated into abutting engagement therewith thus resetting said escapement wheel, and means connecting said coil to a source of electrical energy.

6. High speed stepping apparatus comprising in combination, a rotatable shaft, an escapement wheel rotatable with said shaft, said escapement wheel being provided with oppositely disposed parallel peripheral rows of tooth-like projections, the projections of one peripheral row being radially off-set with respect to the projections of the opposite parallel peripheral row by one-half the circular pitch of the projections of said one row, said wheel also being provided with a reset projection extending away from one peripheral edge thereof, an electromagnet including a core, supporting structure for said apparatus cooperative with said core to form an air gap, an electrically energizable member movable within said air gap, means connecting said last named member to a source of electrical energy to cause said member to move within said air gap, a flexible suspension mounted to said ener-

gizable member, a resilient spring-like member pivoted to said suspension, a U-shaped shuttle carried by said spring-like member and adapted to straddle said peripheral row of projections, said U-shaped shuttle being releasably engageable with alternate rows of said projections upon energization of said electrically energizable member thereby to permit said escapement wheel to escape therepast a tooth at a time, an electromagnet, an armature movable in response to the energization of said electromagnet, means connecting said armature to said spring-like member, and, means connecting said electromagnet to a source of electrical energy whereby when said electromagnet is energized said shuttle is released from engagement with the rows of projections of said escapement wheel and moved into the path of travel of said reset projection of said escapement wheel thus to

permit said escapement wheel to be reset and stopped at a desired position.

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