

Oct. 26, 1965

M. A. LACE
APPARATUS FOR CONTROLLING MAGNETIC PULSE
COUNTING AND FORMING DEVICES

3,214,715

Filed Oct. 17, 1961

3 Sheets-Sheet 1

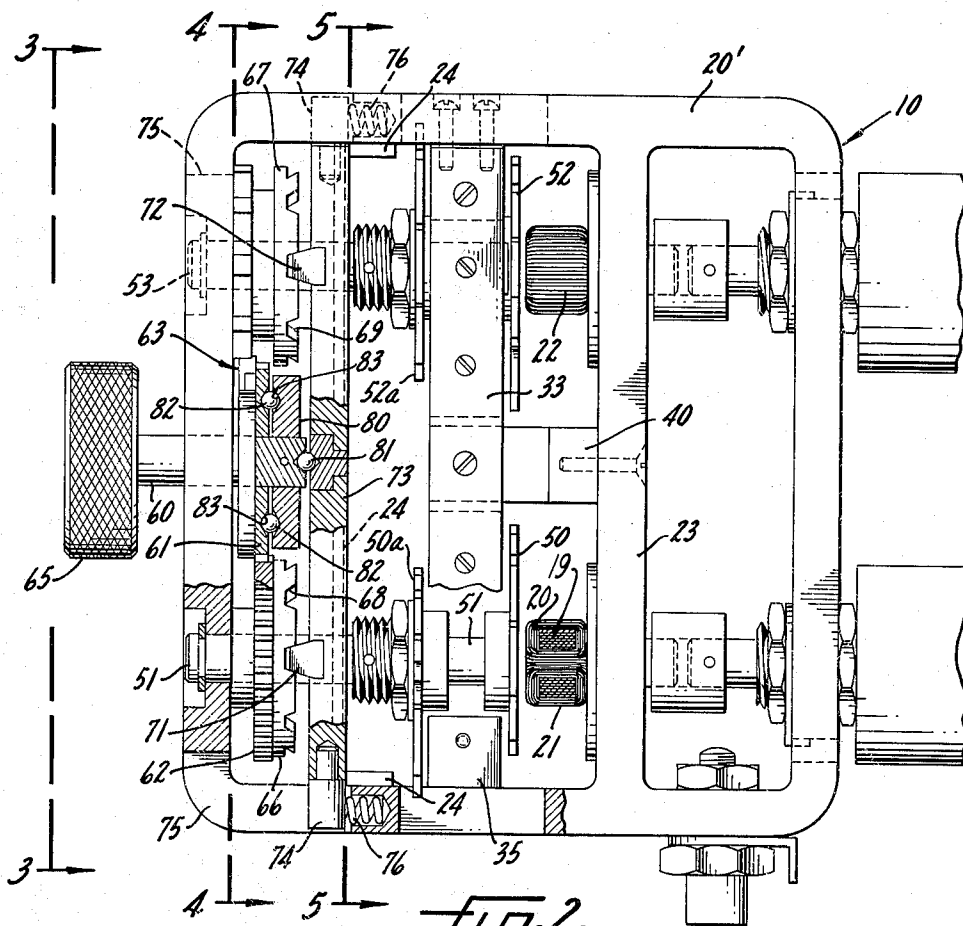


Fig. 2.

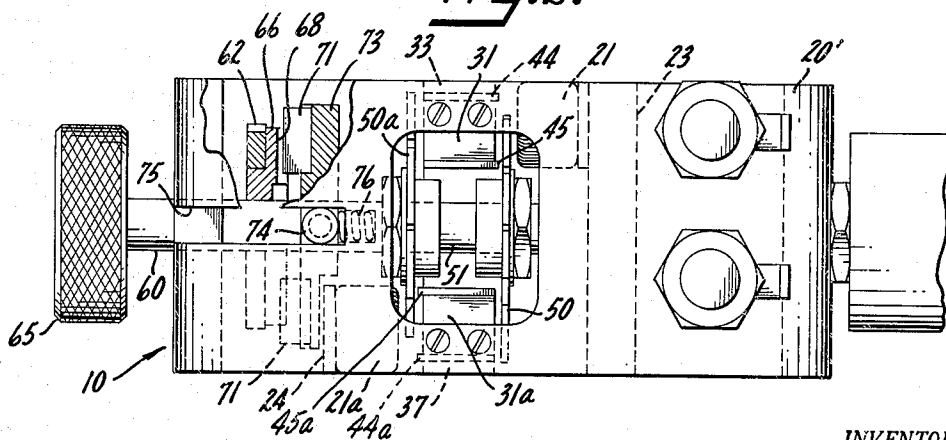


Fig. 1.

INVENTOR.
Melvin A. Lace,
BY *V. A. K. K. K.*
Attorney

Oct. 26, 1965

M. A. LACE
APPARATUS FOR CONTROLLING MAGNETIC PULSE
COUNTING AND FORMING DEVICES

3,214,715

Filed Oct. 17, 1961

3 Sheets-Sheet 2

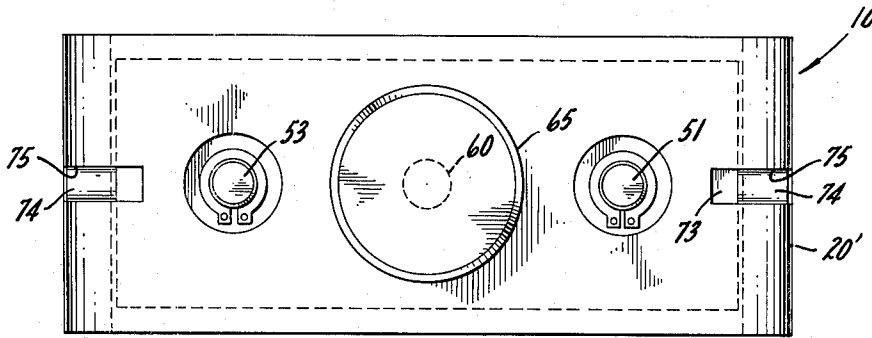


Fig. 3.

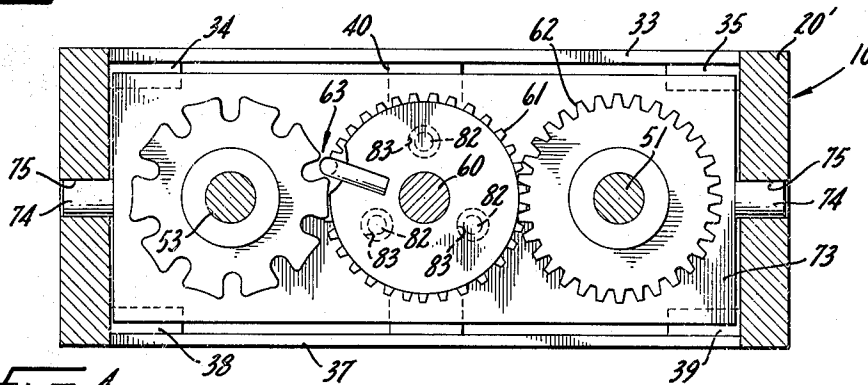


Fig. 4.

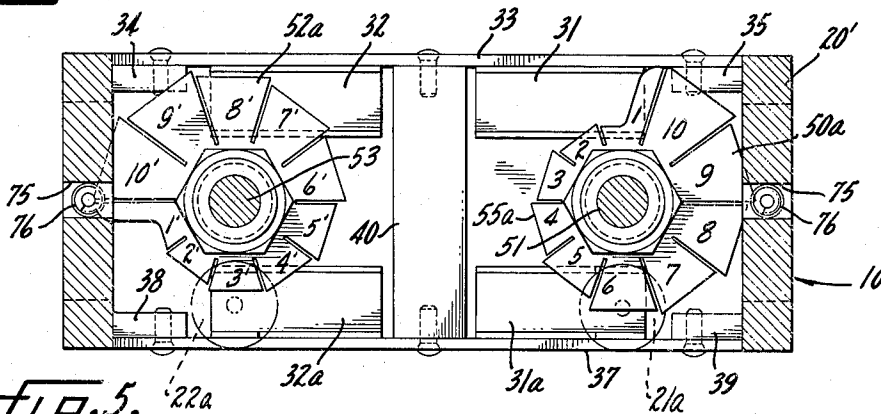


Fig. 5.

INVENTOR.
Melvin A. Lace,
BY *[Signature]*
Attorney

Oct. 26, 1965

M. A. LACE
APPARATUS FOR CONTROLLING MAGNETIC PULSE
COUNTING AND FORMING DEVICES

3,214,715

Filed Oct. 17, 1961

3 Sheets-Sheet 3

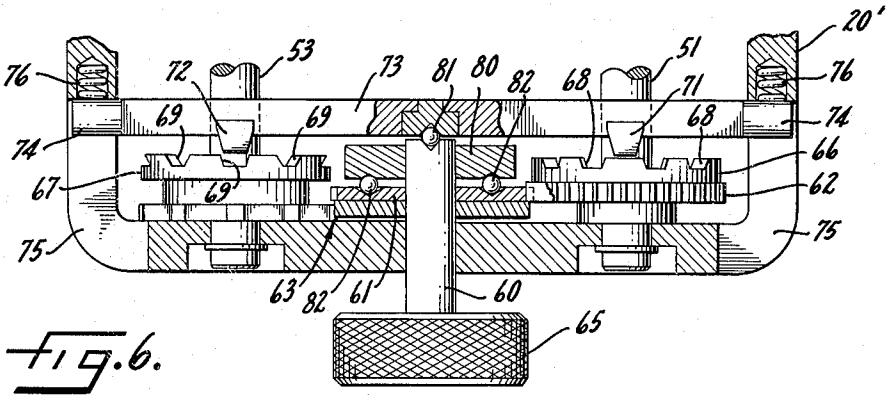


Fig. 6.

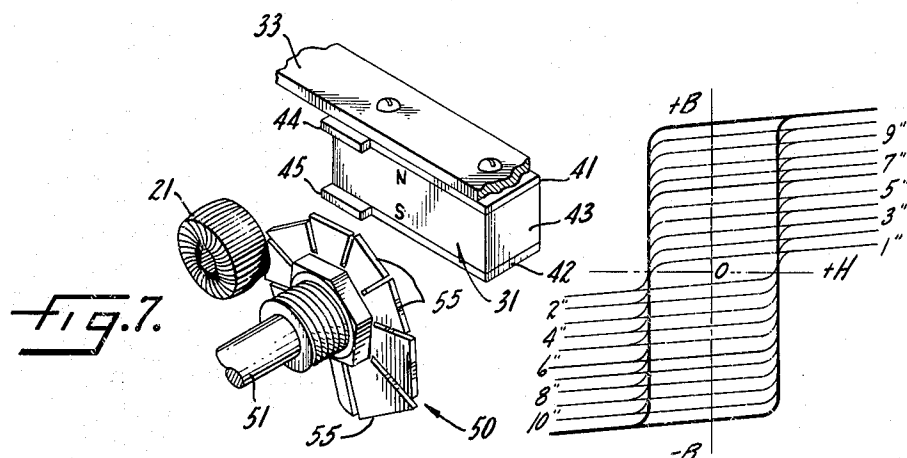


Fig. 7.

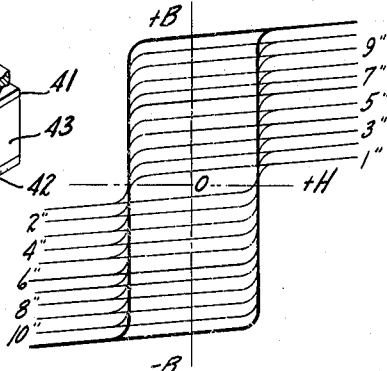


Fig. 9.

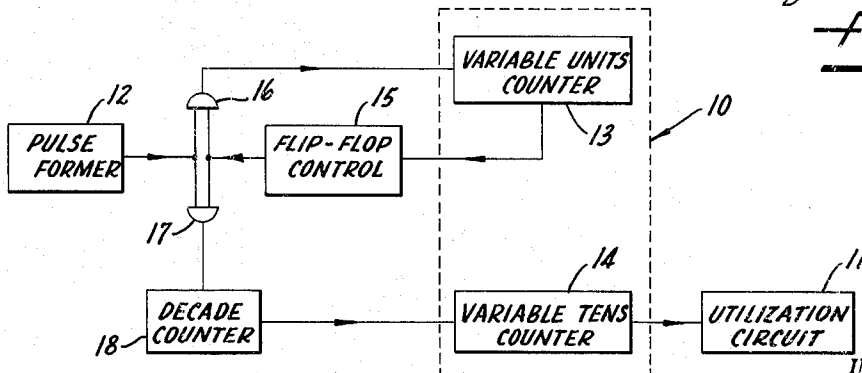


Fig. 8.

INVENTOR.
Melvin A. Lace,
BY *H. A. Hiles*
Attorney

1

3,214,715

APPARATUS FOR CONTROLLING MAGNETIC PULSE COUNTING AND FORMING DEVICES

Melvin A. Lace, Prospect Heights, Ill., assignor to General Time Corporation, New York, N.Y., a corporation of Delaware

Filed Oct. 17, 1961, Ser. No. 145,685

5 Claims. (Cl. 336—110)

This invention relates generally to magnetic devices for counting and forming electrical pulses and, more particularly, to a method and apparatus for controlling the characteristics of such devices.

Pulse forming and counting apparatus is useful for directing or controlling timing logic circuits. Recently developed forms of such apparatus have relied upon saturable reactors incorporating rectangular hysteresis loop core material. Such material exhibits switching characteristics which remain uniform and stable over an extremely wide range of operating conditions during an almost unlimited lifetime. For an example of such apparatus, reference is made to U.S. Patent No. 2,897,380, issued July 28, 1959, to Neitzert. The above desirable characteristics of such core material have also tended to limit the flexibility and versatility of such apparatus since the pulse forming and counting function depends upon the physical relationship between a saturable core and its electrical winding. As a result, a device which counts six pulses of given volt-second content cannot normally count five pulses having the same volt-second content. Additional electrical circuits can be employed to change the volt second content of the drive pulses as desired, or the electrical circuitry of the counter can be adjusted, as by selection of taps on the core winding. Such electric circuitry changes are practical for some applications but do require modification of the counter stage or preceding circuitry.

Alternatively, the concept of using external magnetic flux fields to pre-bias the counter core to a selected residual magnetization level has also been contemplated. Such an approach requires no electrical change or adjustment at the counter stage, and it is the primary aim of the present invention to provide a simple and completely reliable method and apparatus for externally adjusting the count of a saturable reactor type of pulse counting and forming device. Stated in another way, it is an object of the invention to adjust the count of a fixed count saturable core pulse and counting device without electrical alteration or rewinding of the counting device or associated related circuitry.

It is also an object of the invention to provide an apparatus as characterized above which is quite compact and exceptionally rugged. Moreover, it is an object to provide an apparatus of the above described type which results in a temperature stable pulse counting and forming device, even through temperature ranges from -65 to $+200^{\circ}\text{F}$.

Another object is to provide an apparatus of the above character which is inexpensive to manufacture and quite easy to calibrate. A collateral object is to provide an apparatus of the type described which can be adjusted quickly and easily by operators having no special training.

Other objects and advantages of the invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which:

FIGURE 1 is a fragmentary side elevation, partially section, of a device embodying the present invention;

FIG. 2 is a top plan view, partially sectioned, of the device shown in FIG. 1;

FIG. 3 is an end elevation of the device shown in FIG. 2 and is taken along the line 3—3 in FIG. 2;

2

FIGS. 4 and 5 are transverse sections taken approximately along the lines 4—4 and 5—5 respectively in FIG. 2;

FIG. 6 is a fragmentary plan, partially sectioned, of a portion of the device shown in FIG. 2 with the parts in an alternate operating position;

FIG. 7 is a somewhat diagrammatic perspective of a portion of the device shown in FIG. 1;

FIG. 8 is a schematic diagram of a circuit utilizing the device of FIG. 1; and

FIG. 9 is a diagrammatic representation of a hysteresis loop explaining an aspect of the operation of the device of FIG. 1.

While the invention will be described in connection with a preferred embodiment and procedure, it will be understood that I do not intend to limit the invention to that embodiment or procedure. On the contrary, I intend to cover all alternatives, modifications and equivalents as may be included within the spirit and scope of the invention as defined by the appended claims.

Turning now to the drawings there is shown a device 10 embodying the invention and arranged to form a part of a timer circuit shown schematically in FIG. 8. It will facilitate and understanding of the invention to first briefly review the operation of this circuit.

The purpose of the FIG. 8 circuit is to send an energizing electrical pulse to a utilization circuit 11 after a selected number of pulses are received from a pulse former 12. The setting of the device 10 determines the number of pulses from the pulse former 12 which must be received before an output pulse is directed to the utilization circuit 11. The circuit becomes a precise timing circuit if the pulse former 12 is arranged to generate uniform pulses at uniform time intervals. In such a case, the device 10 can accurately control the moment at which an output pulse is sent to the utilization circuit 11.

In the illustrated embodiment, the device 10 includes a variable units counter 13 and a variable tens counter 14, each of which rely upon saturable reactors that deliver an output pulse upon receipt of a plurality of input pulses totalling a given volt-second content. Considering the magnitude of the pulse generated by the pulse former 12, the counters 13, 14 are decade counters, that is, they require receipt of ten input pulses before a single output pulse is transmitted.

The respective counters 13, 14 are settable, in accordance with the invention, to deliver one output pulse after any selected number of standard input pulses from one to ten, have been received. In other words, by properly setting the counters 13, 14, an output pulse to the utilization circuit 11 can be set to occur after a particular number of input pulses have been generated by the pulse former 12. In the arrangement shown, the settable range of required input pulses from the pulse former 12 extends from 11 to 110 so that 99 distinct settings are obtained.

To achieve this range of settings, the units counter 13 operates a flip flop control 15 which controls a normally ON gate 16 and a normally OFF gate 17. The normally ON gate 16 connects the pulse former 12 to the units counter 13 and the normally OFF gate 17 connects the pulse former 12 to a decade counter 18 whose output is directed to the tens counter 14. The output of the tens counter 14 leads directly to the utilization circuit 11.

The decade counter 18 is also a "tens" counter having the same counting characteristics of the counters 13, 14, although not being settable. That is, the counter 18 always requires ten input pulses from the former 12 before developing an output pulse.

To illustrate the operation of the circuit of FIG. 8, it will be assumed that it is desired to set the device 10 so that the circuit 11 is energized when 36 input pulses have been received from the pulse counter 12. To achieve this

3

result, the tens counter 14 is set to 3, for thirty, and the units counter 13 is set to 6, for six. It will be recalled that the flip flop control 15 holds the gate 16 open and the gate 17 normally closed.

The first pulses generated and transmitted from the pulse former 12 pass through the open gate 16 to the variable units counter 13. Since this counter is set for "6," upon receipt of the sixth pulse the counter generates an output pulse to the flip flop control 15, whereupon the normally open gate 16 is closed and the normally closed gate 17 is opened. The 7th pulse from the former 12 is thus directed to the decade counter 18, and subsequent pulses continue to flow to this counter when 10 pulses have been received, an output pulse from the counter 18 is transmitted to the tens counter 14. The pulse former 12 continues to transmit pulses to the counter 18 so that, for every ten pulses received by the counter 18 another pulse is transmitted to the tens counter 14. Since the tens counter 14 is set for "3," upon receipt of the third pulse at the counter 14, indicating that 30 pulses were transmitted to the decade counter 18, an output pulse is generated by the tens counter and transmitted to the utilization circuit 11. Thus, the utilization circuit 11 is energized after 36 pulses have been generated and transmitted by the pulse former 12.

Turning with more particularly to the construction of the device 10, the particular illustrated device is intended for installations which require utmost reliability and hence the device 10 embraces "redundant" circuitry. That is, each circuit element in the device is duplicated so that the device includes two complete circuit mechanisms, connected in parallel, which are completely independent. In keeping with the principle of redundant circuitry, the output of either one of the systems is arranged to complete the desired function. While incorporation and practice of the invention in such an environment is merely exemplary, it is also indicative of the usefulness of the invention in applications where reliability is foremost. For convenience in description, the duplicated parts in each circuit have been given the same reference numerals with the distinguishing suffix *a* to one set.

The units counter 13 and tens counter 14 in devices 10 and 10*a* each include an annular core 19 carrying a toroidal winding 20 (FIG. 2). The cores 19 themselves are preferably tape-wound of magnetic material exhibiting square hysteresis loop characteristics. The winding turns 20 on each core provide the magnetizing, control, reset, and output pulse functions in circuit with transistors, resistors, and voltage source completing each stage, preferably as shown in the United States patent to Neitzert, No. 2,897,380, issued July 28, 1959, and assigned to the assignee of the present invention. These latter circuit elements are not shown in the drawings since their physical placement is not directly involved in the practice of the invention. Instead the insulated core and winding assemblies are identified in the drawings as reactors 21 and 21*a* of the variable units counter stage 13 and as reactors 22 and 22*a* of the variable tens counter 14.

It is important that the reactors be securely positioned as they are each part of a magnetic circuit. Accordingly, upper reactors 21 and 22 are secured, suitably by cement, to an intermediate wall or panel 23 of the box-like frame 20' of assembly 10, and lower reactors 21*a* and 22*a* are likewise fastened to a bracket or panel 24 in the frame. The panels, as well as the remainder of the frame are made of a non-magnetic material, such as brass. As viewed in FIGS. 1 and 2, the axes of the reactors (i.e., the axes of their annular cores 19) are horizontally aligned.

In accordance with the invention, the counters 13, 14 are controlled by disposing their respective reactors in strong magnetic biasing fields and adjusting the external flux through the cores by positioning a magnetic shunt-shield between each core and the field source. In

4

the illustrated embodiment, the external flux fields are generated by magnets 31 and 31*a* disposed adjacent the respective reactors 21 and 21*a*, and magnets 32 and 32*a* disposed adjacent the respective reactors 22, 22*a*. The upper magnets 31, 32 are fixed to an upper brass bar 33 secured to frame bracket flanges 34 and 35 and the lower magnets 31*a* and 32 are secured to a corresponding lower frame for 37 on frame bracket flanges 38 and 39. A central support part 40, also made of non-magnetic material extends between frame bars 33 and 37 to keep the magnets securely aligned in precise spaced relationship with the respective reactors.

The magnets are identically constructed, and the view of magnet 31 in FIG. 7 illustrates the construction of each. A permanently magnetized elongated block 41 is shown which is magnetized through a thickness dimension and held between upper and lower soft iron plates 42 and 43 having projecting pole portions 44 and 45 respectively near one end. The magnet material 41 is preferably a ceramic type made from a sintered barium carbonate and iron oxide mixture and available commercially as "Indox I," marketed by Indiana General Corporation, Valparaiso, Indiana. Such ceramic magnets are chosen here because their high coercive force and low incremental permeability (about 1.1) assures an essentially constant total flux despite demagnetizing influences or changes in the air gap length in the magnetic circuit between the pole pieces 44, 45.

Part of the flux of each magnet extends through the core material of the reactor located adjacent to it. With each magnetic and reactor fixed in place, the amount of magnet flux in each core is controlled by adjusting the reluctance of a shunt path between the magnetic poles to selectively shunt or short-circuit a portion of the magnet flux which would otherwise be carried by a reactor core.

In the preferred embodiment illustrated, the flux of the fixed magnets is selectively shunted by angularly adjustable shields of magnetically permeable material having radial segments of varied size and mounted between the fixed magnets and their respective coils. Toward this end a pair of shields or shunts 50 and 50*a* are mounted on a rotatable shaft 51 so that the shield 50 extends between the coil 21 and its fixed biasing magnet 31 and the shield 50*a* extends between the coil 21*a* and its fixed biasing magnet 31*a*. Correspondingly, a pair of shields 52 and 52*a* are secured to a rotatable shaft 53 and are disposed, respectively, between the coil 22 and its biasing magnet 32 and the coil 22*a* and its biasing magnet 32*a*. The shafts 51 and 53 are journaled in the frame 21. The shields or shunts are suitably made of soft iron which has an incremental permeability of the order of thousands so that the flux in a flux path between the poles 44, 45 through air gaps and a shield portion is limited by the gap length.

As the magnetic shields or shunts are substantially identical, particular reference is made to FIG. 7 for a description of the shield 50 applicable to all of the shields. The shield 50 is made up of ten radial segments 55 having radii of steadily increasing magnitude so that the outer periphery of the shield assumes a stepped, approximately spiral configuration. In the illustrated construction, the shortest of the vanes or segments 55 barely extends into the space between the pole pieces 44 and 45 of magnet 31, whereas the segment 55 with the largest radius overlaps both pole pieces 44, 45 and shunts most of the paths between the poles 44, 45 of the magnet 31 and through the reactor 21. Indeed, in the preferred construction it has been found desirable to form the longest segment 55 of double thickness to assure "short circuiting" of substantially all of the lines of flux flowing between the pole pieces and almost eliminate the effect of the magnet 31 on the reactor 21.

As will be readily apparent, rotation of the shaft 51 causes successive ones of the segments 55 to be disposed between the magnet 31 and the reactor 21. Disposing one

of the magnetically permeable segments 55 between the magnet poles 44, 45 shunts lines of flux from the magnet 31 which would have otherwise passed through the core of the device and thus decreases the effect of the magnet on the core of the reactor. The amount of this short circuiting increases with the radius of the particular segment 55 positioned adjacent the magnet poles 44, 45, which is to say that the shunting flux decreases with the total air gaps from the poles 44, 45 to the nearest vane portions.

The effect of an external magnetic field in the annular core of a counter is to shorten its count, which is to say that the volt-second integration required drive the core from one residual saturation level to the opposite saturation level is decreased. While an annular core itself represents a closed magnetic circuit, the entire core may be regarded as a low-reluctance portion of another magnetic circuit including one of the magnets 31, 31a, 32, or 32a. The net result is the same as if the cross section area of the core were decreased as represented in FIG. 9 where the solid lines indicate the substantially rectangular hysteresis loop of a counter core without external magnetic field bias. The dotted line hysteresis loops labeled 11 to 10 correspond to what are believed to be the effective saturation levels for the core as biased to produce from one output pulse per count of ten drive pulses down to one output pulse per count of one drive pulse. The magnet flux is believed to pass through diametrically opposing portions of the annular core to increase the total core flux in one or the other core portion regardless of the direction of the induced flux in the core.

The size of each segment required for the desired counter calibration is most conveniently determined empirically. The shield 50 is indexed, segment by segment, past the pole pieces 44, 45 of the magnet 31 and portions of the segment are removed until tests indicate that the counter 13 delivers an output pulse following the receipt of the desired number of input pulses. The same procedure is followed for the other counters. Of course, once the particular shape and size of a workable shield has been established for a magnet, counter, and drive pulse of known characteristics, subsequent shields can be correspondingly formed for at least a preliminary calibration. The shape of the exemplary shield 50 particularly facilitates empirical proportioning since the ends of the segments 55 can be readily snapped off or filed down until the desired segment size is reached.

It will be appreciated that recalibration is conveniently minimized by employing a low-permeability permanent magnet for the field source as previously described. Critical adjustment requirements are likewise avoided. This is not to say that electromagnets cannot be employed to bias the cores, provided that precautions are taken to keep the magnetizing force constant or to account for flux changes. The magnetic material of the counter cores is also desirably selected so that effects of temperature changes tend to counteract the effects of temperature changes of the adjacent permanent magnet.

For setting the several shields, a control shaft 60 is journaled in the frame in parallel relation to the shafts 51, 53 and is coupled by gears 61 and 62 to the shaft 51 and by a ten-step Geneva drive 63 to the shaft 53. Thus, rotation of the control shaft 60, which is accomplished in the illustrated instance by manipulating a knob 65 secured to the control shaft, directly rotates the shield shaft 51 and steps the shield shaft 53 through $\frac{1}{10}$ of a revolution for every complete revolution of the shaft 51.

To positively lock the shield shafts 51, 53 in the proper angular positions to dispose the segments of the shields in proper relationship to the respective magnets, the shafts carry annular locking members 66 and 67, respectively, formed with pluralities of notches 68 and 69 that are aligned with the segments 55 of the shields carried by the respective shafts. Cooperating with the notches 68, 69 are locking elements 71 and 72 respectively, mounted on

a locking plate 73. The plate 73 carries end rollers 74 which are slidably disposed in slots 75 formed on either side of the frame. Compressed helical springs 76, seated in the frame 21, bear against the rollers 74 and urge the plate 73 toward the locking members 66, 67 so that the locking elements 71, 72 tend to seat within the notches 68 and 69. It will be readily apparent that with the locking elements 71, 72 seated within respective ones of the notches 68, 69, rotational movement of the shafts 51, 53 is prevented and the shields 50, 50a, 52, 52a are positively locked in position.

In order to release the locking members 66, 67 upon rotation of the knob 65, the control shaft 60 is axially slidable in the frame 21 and provided with a cam 80 to shift the locking plate 73 through a thrust bearing 81. The cam 80 is pinned to the control shaft 60 adjacent the gear 61. The gear 61 and the driving element for the Geneva drive 63 are rotatably mounted on the control shaft 60. A plurality of cam balls 82 are trapped between circular recesses 83 formed in opposed relation on the facing surfaces of the cam 80 and the gear 61.

In operation, rotation of the knob 65 rotates the cam 80 so that the cam balls 82 tend to ride out of their opposed recesses 83. This forces the cam 80, and thus the control shaft 60, away from the adjacent gear 61 so that a force is exerted through the thrust bearing 81 pushing the locking plate 73 against the bias of the springs 76 to the limit of the frame slots 75. This movement clears the locking elements 71, 72 from their respective notches 68, 69.

Further rotation of the control shaft 60 causes the cam 80, through the cam balls 82, to rotate the gear 61 and the driving element of the Geneva gear 63 so that the shield shafts 51, 53 can be positioned as desired. As soon as rotational force on the control shaft 60 is released, the springs 76 urge the locking plates 73 and the control shaft 60 to their original positions whereupon the locking elements 71, 72 enter respective ones of the notches, 68, 69 to lock the shields in their newly selected angular positions.

By means of this locking structure, the radially extending shield segments are always precisely positioned relative to their respective magnets and the operator is not relied on to exactly rotate the knob 64 nor is reliance placed on the locking accuracy of the Geneva drive 63 to insure proper adjustment of the shields.

As will be obvious to those skilled in the art, any suitable indicator or dial markings can be associated with either the control shaft 60 or the shield shafts 51, 53 to indicate the adjusted positions of the shields for the convenience of the operator.

It will, therefore, be apparent that the device 10 can be readily used by persons having no particular specialized training since the operator of the device merely turns the knob 65 to select the number of input pulses from the pulse former 12 at which it is desired to energized the utilization circuit 11. For example, the example previously referred to (a count of 36) is illustrated by the position of the shields in FIG. 5. It can also be appreciated by those familiar with this art that the device 10 is particularly rugged and quite compact even considering the provision of redundant circuitry. A successfully operated unit 10 corresponding to that shown in the drawings measured approximately 4" by 4" by 1½"; and smaller assemblies can be readily made.

In the discussion above, attention has been focused on the counting function performed by the reactors 21, 21a, 22, 22a of the respective counters, but it will be readily appreciated that biasing the reactor cores also diminishes the size of the generated output pulse to the same degree that the count is decreased. This calibrated effect, too, may be employed as desired.

Other sequences or shapes of differently dimensioned magnet shields or shunt paths may, of course, be substituted for the multi-vane rotor described in detail, herein,

and, of course, the biasing control is not limited to decade counters.

I claim as my invention:

1. In a pulse counting and forming device, the combination comprising a saturable annular core formed of substantially rectangular hysteresis loop material, a winding on said core for driving the core from one residual saturation state in the other upon receipt of a given volt-second product, a magnet positioned with its poles closely adjacent said core so that at least a portion of the flux field of said magnet passes through said core, to change the residual magnetic state of said core and thus change the effective volt-second content required to drive it from one saturation state to the other, and a shield of permeable material mounted for movement to an operative position between said magnet and said core so that when in operative position said shield shunts the lines of flux in said field to diminish the effect of said field on said core and thus decrease the effective volt-second content of the core.

2. In a pulse counting and forming device, the combination comprising, a saturable closed loop core formed of substantially rectangular hysteresis loop material, a winding on said core for driving the core from one residual saturation state to the other upon receipt of a given volt-second product, a low permeability magnet positioned with its poles adjacent said core so that said core is in the field of said magnet, a shield of highly permeable material mounted for movement transversely between said magnet and said core to adjustably diminish the effect of said field on said core, and means for transversely positioning said shield so as to vary the amount of permeable material between said magnet and said core and thus select the pulse volt-second content required to saturate said core.

3. In a pulse counting and forming device, the combination comprising, a saturable annular core formed of substantially rectangular hysteresis loop material, a winding on the core adapted to be connected to a current source for driving the core from one saturation state to the other, a magnet positioned with its poles closely adjacent said core so that said core is in the field of said magnet, to decrease the effective volt-second content of the core a shield of permeable material having portions of graduated size mounted for movement transversely between said magnet and said core to selectively diminish the effect of said field on said core, and means for transversely positioning said shield so as to select the size of the shield portion between said magnet and said core and thus control the pulse volt-second content required to saturate said core.

4. In a pulse counting and forming device, the combination comprising, a frame, a saturable reactor mounted on said frame, said reactor including a core formed of substantially rectangular hysteresis loop material, a magnet mounted on said frame with the poles of the magnet closely adjacent said core, a permeable shield journaled on said frame and having radially extending segments swingable between said magnet and the adjacent core, said shield having a locking member rotatable therewith and formed with a plurality of notches, said notches corresponding to respective ones of said segments, a locking plate slidably mounted on said frame and having a locking element engageable with the notches in said member, means biasing said plate toward said member so that said element enters one of said notches and normally locks said shield against rotation, a control shaft journaled in said frame and being rotatably coupled to said shield, and means for shifting said plate against its bias to unlock said shield incident to rotation of said control shaft.

5. In a pulse counting and forming device, the combination comprising, a frame, a saturable reactor mounted on said frame, said reactor including a core formed of substantially rectangular hysteresis loop material, a magnet mounted on said frame with the poles of the magnet closely adjacent said core, a permeable shield journaled on said frame and having radially extending segments of different radii swingable between said magnet and said core so as to diminish the effect of the magnetic field on the core with the amount of said diminution depending upon the angular position of said shield, said shield having a locking member rotatable therewith and formed with a plurality of notches, said notches corresponding to respective ones of said segments, a locking plate slidably mounted on said frame and having a locking element engageable with the notches in said member, means biasing said plate toward said member so that said element enters one of said notches and normally locks said shield against rotation, a control shaft journaled in said frame and being rotatably coupled to said shield, and means for shifting said plate against its bias to unlock said shield incident to rotation of said control shaft.

References Cited by the Examiner

UNITED STATES PATENTS

2,026,060	12/35	Pratt	336—110 X
2,521,963	9/50	Beusman	336—79 X
2,707,271	4/55	Thompson et al.	336—186 X
2,897,380	7/59	Neitzert.	

JOHN F. BURNS, *Primary Examiner.*