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RELAY AND CIRCUITS THEREFOR

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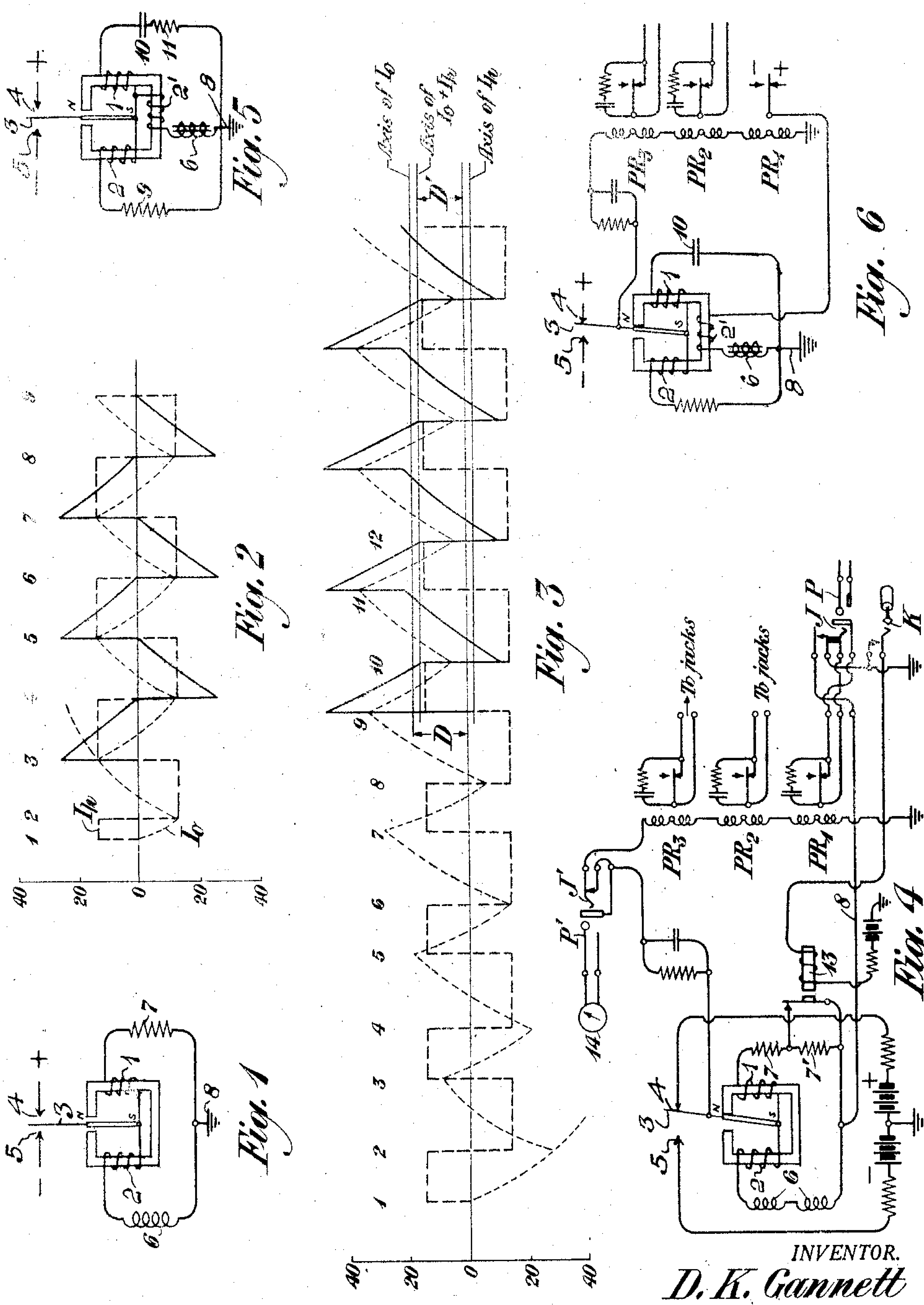

INVENTOR.

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BY

ATTORNEY

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UNITED STATES PATENT OFFICE.

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RELAY AND CIRCUITS THEREFOR.

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To all whom it may concern:

Be it known that I, Danforth K. Gannett, residing at Elmhurst, in the county of Queens and State of New York, have invented certain Improvements in Relays and Circuits Therefor, of which the following is a specification.

This invention relates to relays of the vibrating armature type, and more particularly to arrangements for causing such relays to operate with minimum bias effects.

While relays of this character are capable of a wide variety of uses, one of the methods of employing the vibrating relay of this invention is for the purpose of generating "telegraph reversals." Such reversals consist of a steady train of impulses or dots, the succeeding impulses being usually of opposite signs, and currents of this character may be utilized for testing purposes in connection with telegraph apparatuses, repeater sets, etc. When used for such purposes, it is extremely desirable that the vibrating relay operate with a minimum amount of bias, or, in other words, that the reversals or succeeding impulses of opposite polarity be of uniform periodicity and duration, so that if adjustments of a device are to be made by means of these reversals, any liability of error due to the bias of the testing current itself will be eliminated. Such bias is exemplified in a periodically reversing current by either a longer resistance or a greater amplitude of the current pulses of one polarity. It is, in general, the object of the invention to provide arrangements for a vibrating relay which will cause the relay to be very stable with respect to bias so that imperfect adjustment of the relay or other variable factor will not introduce perceptible bias into the generated reversals.

The invention may be more fully understood from the following description when read in connection with the accompanying drawing in which Fig. 1 is a schematic circuit diagram of a preferred embodiment of the invention.

Figures 2 and 3 are graphic illustrations of the operation of the device of the present invention under different conditions, Fig. 4 illustrates a form of testing circuit to which the vibrating relay arrangement of the present invention may be applied, Fig. 5 illustrates a modification of the arrangement shown in Fig. 1, in which the winding for correcting bias of the relay is independent of the operating winding of the relay and Fig. 6 illustrates a still further modification in which the correcting function of one relay is controlled by the operation of another relay.

Referring to Fig. 1, a polar relay having windings 1 and 2 and an armature 3 is illustrated, the armature 3 being adapted to vibrate between fixed contacts 4 and 5, one of which is connected to positive battery and the other of which is connected to negative battery, the other terminals of these batteries being connected to ground. A suitable inductance 6, which preferably has a high time constant, is connected in circuit with the winding 2, and a resistance 7 is included in circuit with the winding 1, the circuits of both windings being arranged in parallel and connected to ground at 8.

The windings 1 and 2 are so constructed that a circulating current flowing through the windings in series produces and additive effect, that is, both windings under these circumstances tend to shift the armature in the same direction. The current flowing through the two windings in parallel to or from the mid-point, however, will produce opposing effects upon the armature. The circuit arrangement is such that, when the armature is resting upon one contact, the current flowing through the winding 2 and the inductance 6 will be in such a direction as to tend to shift the armature to the opposite contact, while the current flowing through the winding 1 and the resistance 7 will be in such a direction as to hold the armature against the contact. These currents will hereinafter be referred to as operating and holding currents respectively, and the windings 2 and 1 will likewise be referred to as operating and holding windings respectively.

The operation is as follows:

Let us suppose that the armature 3 is resting against one of the contacts, for example, the contact 4, and that a positive potential with respect to ground is suddenly applied to the contact 4, by closing a switch, for example. A current is immediately established through the holding winding 1 and the resistance 7, tending to lock the armature against the contact 4. It will be observed that the full battery potential is applied to the terminals 3 and 8 of the circuit including the winding 1, so that the current flowing through the winding 1 will be independent of the resistance or inductance of the circuit including the winding 2. Consequently, the current which immediately flows through the holding winding 1 maintains a steady value so long as the armature 3 remains against the contact 4.

As soon as the battery potential is applied to the contact 4, however, a current starts to build up in the circuit including the winding 2, but, due to the time constant of the inductance 6, it takes an appreciable time for this current to build up. As soon as this operating current reaches a value sufficient to overcome the effect of the holding current flowing through the winding 1, the armature 3 leaves the contact 4. The instant this occurs the holding current through the winding 1 ceases, and a circulating current due to the discharge of the energy stored in the magnetic field in the inductance 6 flows through said inductance, through the resistance 7 and through the windings 1 and 2 in series. This current flows through the winding 2 in the same direction as the current originally flowing from the contact 4, but it flows through the winding 1 in a direction opposite to that of the holding current, so that the winding 1 now aids the winding 2 to sharply kick the armature over against the negative contact 5. As soon as the armature rests against the contact 5, the holding current flows through the winding 1 in the same direction as the circulating current, but in a direction opposite to that of the previous holding current, so that the winding 1 tends to hold the armature against the contact 5. The potential now applied to the winding 2 is in a direction opposite to that of the previous operating potential, so that the current built up in the inductance 6 begins to decay until it falls to zero and then begins to build up in the opposite direction. When the current builds up in the opposite direction through the winding 2 to a value sufficient to overcome the holding current flowing through the winding 1, the armature 3 leaves the contact 5 and a circulating current flows through windings 1 and 2 in series in such a direction that winding 1 assists the winding 2 to sharply shift the armature to contact 4.

If reference is now had to the graphic showing of Fig. 2 in which the dashed line I_h represents the holding current and the dotted line I_o represents the operating current, it will be seen that it took a longer time for the current in the operating winding to build up in a direction to shift the armature from contact 5 to contact 4 than it did for the operating current to build up to shift the armature originally from contact 4 to contact 5. This is for the reason that during the first semicycle the operating current only had to build up from zero, while during the second semicycle a sufficient time must elapse for the current to decay from the built-up value to zero and then build up to an operating current in the opposite direction. At the end of the second semicycle when the operating current through the winding 2 has reached a sufficient value to again shift the armature from contact 4 to contact 5, the holding current through the winding 1 will hold the armature 3 against the contact 5 as before. The operating current through the winding 2, however, begins to decay until it becomes zero and builds up in the opposite direction to a value sufficient to again shift the armature. Since the current builds up to the same value during each semicycle (although in the opposite direction), the same length of time now elapses between the shifting of the armature to the contact 5 and the shifting of the armature back to the contact 4 as elapsed during the preceding semicycle. A steady state has now been reached, and the armautre will continue to automatically shift back and forth at equal intervals, as will be apparent from the curve of Fig. 2, in which the effective current operating upon the armature (that is, a current equal to the algebraic sum of the operating and holding currents) is indicated by the full line curve, this curve commencing in the diagram at the point where the steady state conditions begins. The frequency of vibration of the armature may be easily adjusted by means of the resistance 7 which controls the value of I_h. The larger I_h is made the longer will be the time interval before I_o builds up to a value sufficient to overcome I_h.

The curves in Fig. 2 were plotted from the calculations made in accordance with formulæ which will be given hereinafter. In making these calculations, and hence in plotting the curves, the time of travel of the relay armature was neglected, the constants of the relay windings were neglected, and it was assumed that the relay shifted its armature just when the operating current reached a value equal to that of the holding current, but in the opposite direction. These assumptions involve only a very slight error, and hence the curves of Fig. 3 substantially represent the operation of the relay.

It will be seen that a relay such as illustrated in Fig. 1 and operating as indicated in Fig. 2 will be subject to bias to a very small extent only, as the force tending to pull the armature away from the contact is roughly proportional to the length of time that the armature has remained on said contact. In other words, the longer the armature rests upon a given contact the greater becomes the value to which the operating current builds up, and hence the greater becomes the force tending to shift the armature from the position in which it is resting.

In order to more fully understand the correcting action against bias effects, let us suppose that, instead of permitting the relay to operate automatically as above described, the armature of the relay be forcibly operated at the same speed as its free vibrations, but with a 20% bias, that is, with the armature resting upon the positive contact, a time only eight-tenths as long as indicated in the curve of Fig. 2 and on the negative contact a time one and two-tenths as long as indicated in Fig. 2. The currents will then take the form indicated by the curves of Fig. 3.

Referring to Fig. 3, it will be observed that when the positive potential is applied to the armature of the relay the operating current begins to build up in the negative direction and continues to so build up for eight-tenths of a semicycle. As this period is much longer than the first semicycle shown in Fig 2, the operating current builds up to a much greater value than that necessary to overcome the holding current before the armature shifts. As soon as the armature shifts, the operating current begins to decay and to build up in the opposite direction, this operation continuing for one and two-thirds semicycles. Owing to the great value in the negative direction to which the operating current has been built up, this time, while greater than that of the previous reversal, does not permit the operating current to build up in the positive direction to a value equal to the negative operating current when the next reversal takes place at the point marked 3. The current now begins to decay and build up in the opposite direction until the reversal at the point marked 4 takes place. The operating current does not in this instance build up to as great a value as at the point marked 2. For each succeeding cycle, the operating current builds up to a greater positive value but builds up to a smaller negative value until a steady condition is reached, as indicated at the point marked 9, at which point the operating current attains its greatest positive value. At the point designated 10, the operating current has not been permitted to decay sufficiently to reach zero, before the armature is again shifted. From this point on the operating current passes through the same variations for each succeeding cycle.

It will be observed that after the steady state condition is reached at the point 9 the axis of the operating current is shifted in a positive direction a distance marked D. This represents an effective direct current through the operating winding upon which direct current an alternating current is superposed. This direct current component is in such a direction as to tend to counteract the bias. The holding current, on the other hand, has shifted in a negative direction to the extent indicated by the horizontal line marked axis of I_h. This axis is drawn so that the area included within the dashed line curve corresponding to a negative semicycle will be equal to the area circumscribed above said line by the dashed lines of the positive semicycle. The shifting of the axis of I_h represents the effective bias due to the prolongation of the negative semicycle. and it will be apparent that the shifting of the axis of I_o in the positive direction is much greater than is necessary to overcome the negative shifting of the axis of I_h. The resultant current operating upon the armature is indicated by the full line curve, and its axis has shifted in a positive direction a distance marked D′. This represents the effective restoring current which tends to oppose the force that produces the bias. For the conditions and circumstances assumed in the drawing, the effective restoring current is about equal to the maximum normal current through either winding. The restoring current increases rapidly in amplitude with the magnitude of the forces tending to produce bias. This results in very stable operation of the relay. In practice, the constants of the circuit should preferably be chosen so that the relay core is not saturated by the operating flux.

The presence of the restoring force represented by D may be explained physically by noting that as the relay armature 3 vibrates, a periodically reversing E. M. F. is impressed across the circuit 3—2—6—8. If the operation of the relay is slightly biased, the armature 3 resting longer on one contact than on the other, the Fourier series representing the E. M. F. wave would possess a small D. C. voltage component. The D. C. impedance of winding 2 and inductance 6, however, is small compared with the A. C. impedance at the frequency of vibration of the relay and therefore the current which flows will possess a relatively large D. C. component notwithstanding that the D. C. voltage is small. This D. C. component is represented by D in Fig. 4 and as noted above is in such a direction as to strongly oppose the forces which tend to bias the operation of the relay.

As has already been stated, the curves of Figs. 2 and 3 were computed from formulæ. The formulæ are derived as follows:

Given inductance L and resistance R in series with source of voltage which applies alternately e and $-e$ for periods t_1 and t_2, respectively. L and R correspond with the constants of inductance 6 in **Fig. 1.** **Taking** $t=O$ when the voltage changes from $-e$ to $+e$, the current is

$$i=I-(I-I')E^{-wt}$$

where I is $\frac{e}{R}$, I' is the current in the circuit when $t=O$, w equals $\frac{R}{L}$ and E is the base of the Naperian logarithms.

Let $I'=-k_1I$

$$i=I[l-(l+k_1)E^{-wt}]$$

Let the value of i when $t=t_1$ be k_2 I. Then

$$i_1=I[l-(l+k_1)E^{-wt}l]=k_2I$$

Let it be supposed that the applied voltage is reversed when $t=t_1$.

Let the value of i when $t=t_1+t_2$ be k_3I. Then

$$i_2=-I[l-(l+k_2)E^{-wt}2]=-k_3l$$

But when the steady-state condition is reached, $k_3=k_1$. From these expressions

$$k_1=\frac{l-2E^{-wt}2+E^{-w(t_1+t_2)}}{l-E^{-w(t_1+t_2)}}$$

and

$$k_2=\frac{l-2E^{-wt}l+E^{-w(t_1+t_2)}}{l-E^{-w(t_1+t_2)}}$$

The extreme values of current are $-k_1$I and k_2I. The location of an axis half way between these values is given by

$$\frac{k_2-k_1}{2}=\frac{E^{-wt}2-E^{-wt}l}{l-E^{-w(t_1+t_2)}}=D$$

When the time constant, $\frac{L}{R}$, of the inductance is equal to or larger than t_1, D is very approximately equal to the distance to the axis so placed that the areas of the curve on each side of it are equal. In other words it very closely represents the value of the D. C. component of the current which flows.

When $t_1=t_2$, D=O. For this condition,

$$k_1=k_2=\frac{l-E^{-wt}l}{l+E^{-wt}l}=k.$$

This last expression gives the amplitude of the current peaks in an inductive circuit when a voltage consisting of periodic unbiased reversals is applied.

As an example of the manner in which the circuit arrangement of Fig. 1 may be utilized, attention is called to the telegraph testing circuit illustrated in Fig. 4. The relay comprising the windings 1 and 2 and armature 3 vibrating between contacts 4 and 5, has an inductance 6 connected in series with the winding 2 and resistances 7 and 7′ in series with the winding 1. The ground connection 8 extending from the terminals of the resistance and inductance legs passes over a normally open contact of the jack J, so that when the plug P is inserted in the jack, the contact is closed, thereby completing the operating circuit. As the armature 3 is directed against one of the contacts, the full battery potential to ground is applied to the windings of the relay and the relay commences to operate as already described. The armature 3 has a connection 12 extending through a contact of a jack J′ and through the windings of polar relays PR_1, PR_2, PR_3, etc., to ground, so that successive positive and negative impulses pass over the contact 3 of the master relay and through the condenser and resistance 14 and through the windings of the relays PR_1, PR_2, PR_3, etc. These relays transmit successive unbiased pulses over the jacks such as J to suitable testing circuits. The condenser and resistance arrangement 14 are for the purpose of causing a large momentary current to flow through the windings of relays PR_1, PR_2, PR_3, etc., at each instant of transfer of armature 3 from contact 4 to 5 or from contact 5 to 4, so that relays PR_1, PR_2, PR_3, etc., will be very positively operated and will not introduce any bias of their own. The frequency at which the master relay vibrates will depend upon the resistance in series with the winding 1. This resistance may be varied by operating a key K which controls the circuit of relay 13 adapted to remove a short circuit from about the resistance 7′, thereby increasing the effective resistance in series with the winding 1. When the key K is operated and the short circuit is removed from about resistance 7′, the frequency of the master relay will be increased. A suitable milliammeter 14 may be plugged into the jack J′ by means of the plug P′ in order to check up the action of the master relay by means of the reading of the milliammeter.

In the arrangement of Fig. 1, the relay winding 2 performs a double function of acting as an operating winding and also as a correcting winding. As an operating winding, its function is to shift the armature from the contact upon which it is at the moment resting to the opposite contact as soon as the operating current has built up to a value greater than the holding current through the winding 1. As a correcting winding, its function is to apply a force to the armature tending to overcome any biasing forces acting upon the armature. These functions may, however, be separated and performed by different windings. The arrangement shown in Fig. 5 illustrates one method of separating the functions.

In Fig. 5, winding 1 is the holding winding and winding 2 is the operating winding. A resistance 9 is connected in series with the operating winding and a capacity 10 and small resistance 11 are connected in series with the holding winding. The operation of the circuit thus far described will be as follows. Assuming that the armature 3 rests against the positive contact 4 and that the circuit is closed by a suitable switch for example, a positive current of full normal value at once flows through the operating winding 2 and the resistance 9. This current is independent of the conditions of the circuit through the winding 1, as the full battery potential is applied across the terminals of the circuit 2—9—8. At the same instant, however, a holding current flows through the winding 1 and charges up the capacity 10. The value of this current will be greatest at the instant of closing the circuit and, as the capacity charges up, the current through the winding 1 will decrease. The holding current, at the instant of closing the circuit, is greater than the operating current through the winding 2, but when it decreases to a value slightly less than the operating current through the winding 2, the operating winding acts to shift the armature to the opposite contact 5. An operating current now flows through the winding 2 in the opposite direction and a holding current also flows through the winding 1 in the opposite direction. The holding current again tends to hold the armature against the contact 5 until it becomes less in value than the operating current, whereupon the operating winding shifts the armature back to the contact 4 and this process continues indefinitely.

The circuit thus far described has no effect to overcome bias for the reason that the impedance of the circuit 2—9—8 is practically the same for the alternating current components as it is for the direct current component which results from bias. In order to overcome the effect of bias, a third winding 2′ is provided, which is so connected as to be energized over the contacts 4 or 5, as the case may be. This winding is so poled that when the armature is resting upon a given contact the current flowing through the winding tends to shift the armature away from the contact. An inductance 6 is included in circuit with the correcting winding 2′. This inductance makes the impedance of the circuit of the winding 2′ very high for the alternating current components resulting from the shifting of the armature between the contacts 4 and 5. Its resistance to direct current, however, is quite low. In the normal operation of the relay, if there is no bias tending to hold the contact against one armature longer than the other, there will be no direct current component and consequently the effect of the winding 2′ upon the operation of the circuit is inappreciable. As soon as the operation of the relay becomes biased, however, so that the armature rests longer upon one contact than upon the other, a resultant unidirectional current component flows through the winding 2′ and the direction of this component is such that the winding creates a constant pull upon the armature in a direction opposite to the biasing effect.

It is not even necessary that the correcting winding be energized over the armature of the vibrating relay, as illustrated in Fig. 5, but this winding may be energized over the armature of any other relay in a system of relays controlled by the vibrating relay. For example, Fig. 6 shows in simplified form how the circuit arrangement of Fig. 4 may be modified to permit of controlling the correcting winding 2′ from one of the polar relays PR_1, PR_2 or PR_3. In the case illustrated, the relay PR_1, which in the circuit of Fig. 4 supplies current reversals to a testing circuit, for example, is utilized for controlling the winding 2′. To this end, the winding 2′, instead of being connected to the armature 3 of the master relay, is connected to the armature of the polar relay PR_1 and the contacts of said polar relay are connected to positive and negative sources of potential respectively. Consequently, if, for any reason, the operation of the master relay becomes biased and its armature rests longer upon one contact than the other, the polar relay PR_1 will so operate that its armature rests longer upon the corresponding contact than the other contact. As a result, a direct current component flows through the winding 2′ in such a direction as to oppose the biasing effect upon the armature 3. The inductance 6 is provided in circuit with the winding 2′ as before so that the winding is practically unaffected by alternating current components owing to its high impedance thereto, while its resistance is quite low to direct current components.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated without departing from the spirit of the invention as defined in the appended claims.

What is claimed is:

1. A vibrating relay system including a polar relay having an operating winding, a holding winding and an armature adapted to rest upon either of two contacts connected to opposite potentials, means whereby when the armature rests upon either of the contacts a steady current flows through the holding winding tending to hold the armature against that contact and means whereby a gradually increasing operating current is built up through the operating winding to shift the armature against the opposite contact.

2. A vibrating relay system including a polar relay having an operating winding, a holding winding and an armature adapted to rest upon either of two contacts connected to opposite potentials, means whereby when said armature rests against either of the contacts a current flows through the holding winding in such a direction as to tend to hold the armature against the contact and an inductance in circuit with the operating winding whereby a gradually increasing operating current is built up through the operating winding to shift the armature against the other contact.

3. A vibrating relay system including a polar relay having an operating winding, a holding winding and an armature adapted to rest upon either of two contacts connected to opposite potentials, means whereby when said armature rests against either of the contacts a uniform holding current flows through the holding winding in such a direction as to tend to hold the armature against the contact and an inductance in circuit with the operating winding whereby a gradually increasing current is built up through the operating winding in such a direction as to shift the armature to the opposite contact.

4. A vibrating relay system including a polar relay having an operating winding, a holding winding and an armature adapted to rest upon either of two contacts connected to opposite potentials, means whereby when the armature rests against either contact a current flows through the holding winding in such a direction as to tend to hold the armature against the contact and a current is built up in the operating winding in such a direction as to shift the armature to the opposite contact and the elements of the relay system being so proportioned that the force tending to pull the armature away from the contact is roughly proportional to the length of time the armature has been on the contact.

5. A vibrating relay system including a polar relay having an armature adapted to be shifted to either of two positions, and magnetic means for periodically shifting said armature, a correcting winding associated with said relay, connections for said winding whereby when the armature of said relay is shifted in either direction by said magnetic means, said winding will tend to shift it in the opposite direction, and means operating, when forces are present tending to bias the action of said armature, to produce an effective restoring force in said winding in a direction to oppose said biasing forces.

6. A vibrating relay system including a polar relay having an armature adapted to be shifted to either of two positions, and magnetic means for periodically shifting said armature, a correcting winding associated with said relay, connections for said winding whereby, when the armature of said relay is shifted in either direction by said magnetic means, said winding will tend to shift it in the opposite direction, and means operating when forces are present tending to bias the action of said armature, to produce an effective restoring force which increases with increase of the biasing forces and which is in a direction to oppose said biasing forces.

7. A vibrating relay system including a polar relay having an armature adapted to be shifted to either of the positions, and magnetic means for periodically shifting said armature, a correcting winding associated with said relay, connections for said winding whereby, when the armature of said relay is shifted in either direction by said magnetic means, said winding will tend to shift it in the opposite direction, and means operating when forces are present tending to bias the action of said armature, to produce an effective direct current in said correcting winding in such a direction as to oppose said biasing forces.

8. A vibrating relay system, including a polar relay, having an armature adapted to be shifted to either of two positions, and magnetic means for periodically shifting said armature, a correcting winding associated with said relay, connections for said winding whereby, when the armature of said relay is shifted in one direction by said magnetic means, current will flow through said winding in one direction and when the armature of the relay is shifted in the other direction by said magnetic means, current will flow through said winding in the opposite direction, and means operating, when forces are present tending to bias the action of said armature, to produce an effective direct current in said correcting winding in such a direction as to oppose said biasing forces.

In testimony whereof, I have signed my name to this specification this 15th day of December, 1922.

DANFORTH K. GANNETT.