

Dec. 8, 1931.

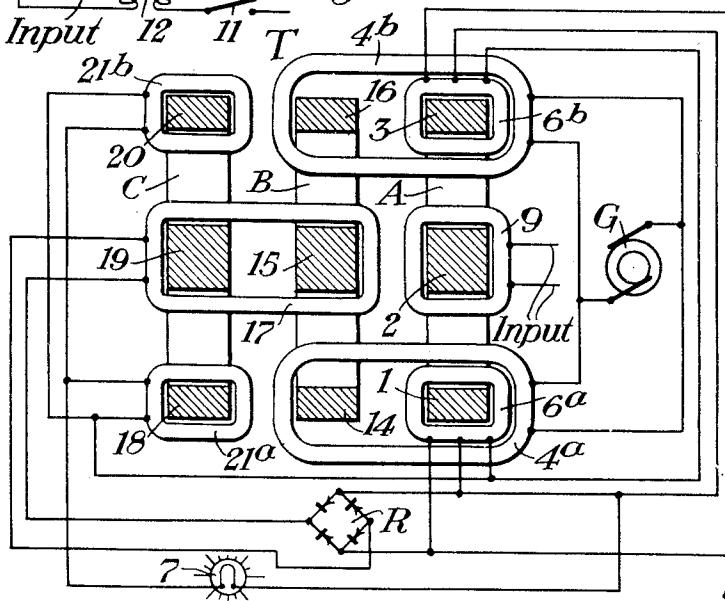
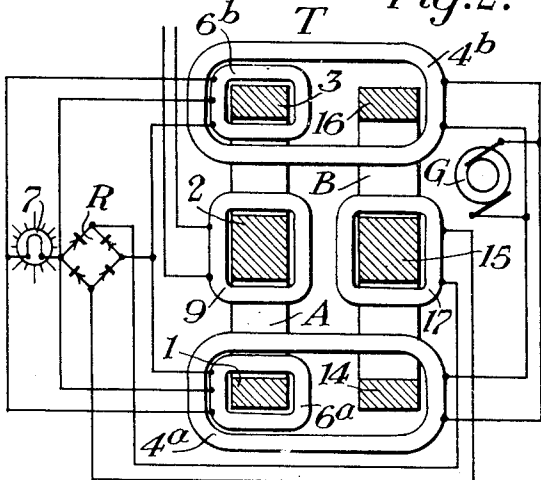
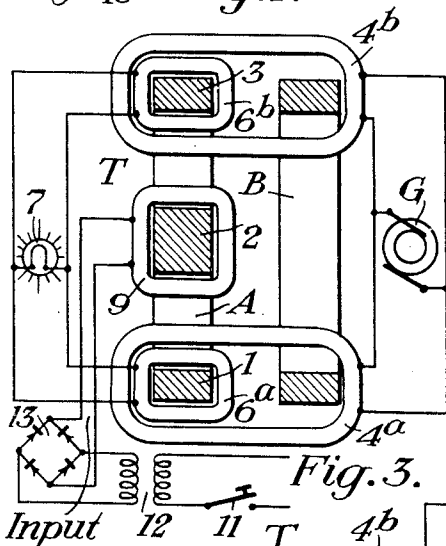
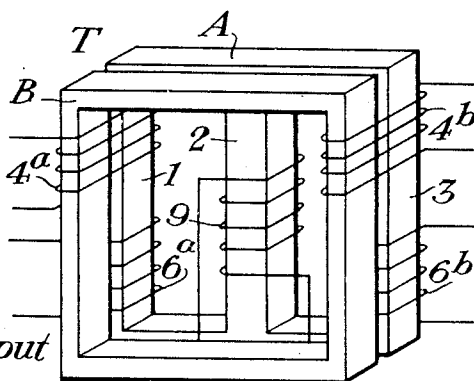
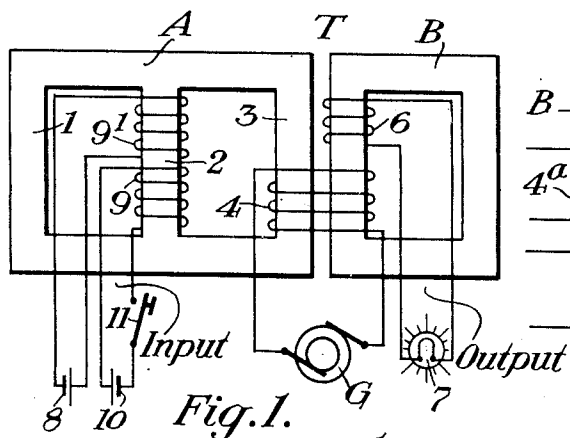
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1,835,209

ELECTRICAL TRANSLATING APPARATUS

Filed June 23, 1930

2 Sheets-Sheet 1



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ELECTRICAL TRANSLATING APPARATUS

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2 Sheets-Sheet 2

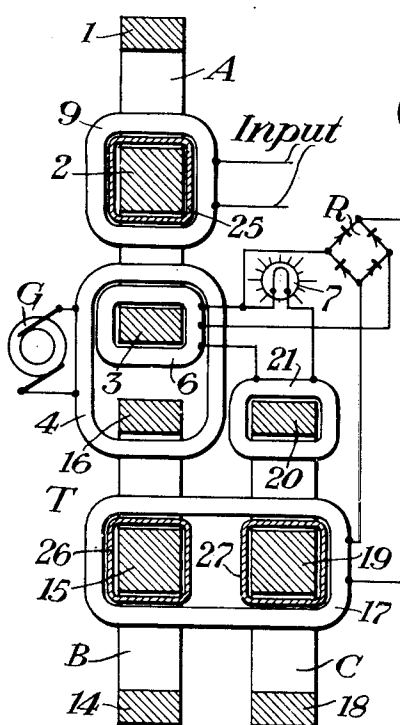


Fig. 6.

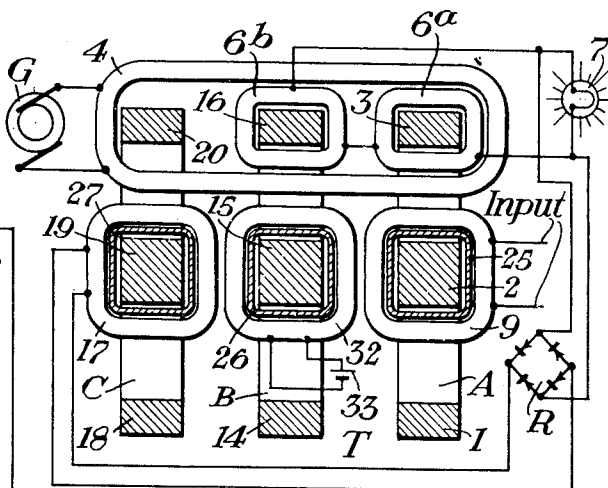


Fig. 7.

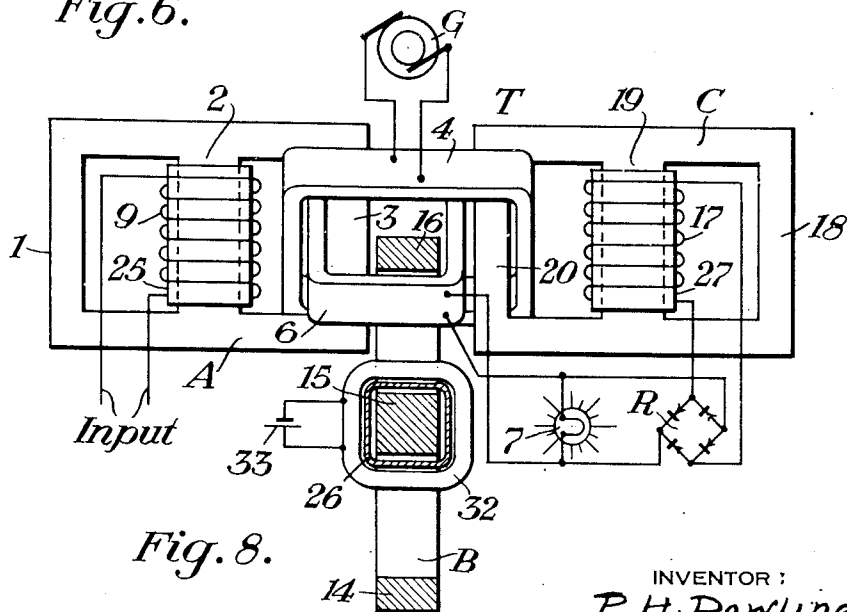


Fig. 8.

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ELECTRICAL TRANSLATING APPARATUS

Application filed June 23, 1930. Serial No. 463,019.

My invention relates to electrical translating apparatus, and particularly to apparatus of the type comprising an input circuit which is at times supplied with current, and an output circuit in which the flow of current is controlled in accordance with the current supplied to the input circuit.

One feature of my present invention is the provision of electrical translating apparatus of the type described in which the current in the output circuit is decreased in response to an increase in the current supplied to the input circuit.

I will describe several forms of electrical translating apparatus embodying my invention, and will then point out the novel features thereof in claims.

In the accompanying drawings, Fig. 1 is a diagrammatic view illustrating one form of electrical translating apparatus embodying my invention. Fig. 2 is a perspective view showing a modified form of electrical translating apparatus embodying my invention. Fig. 3 is a view, partly diagrammatic and partly in section, of the apparatus shown in Fig. 2. Figs. 4, 5, 6 and 7, are sectional views showing other forms of electrical translating apparatus embodying my invention. Fig. 8 is a diagrammatic view, partly in section and partly in elevation of still another form of electrical translating apparatus embodying my invention.

Similar reference characters refer to similar parts in each of the several views.

Referring first to Fig. 1, the reference character T designates a transformer which, as here shown, comprises two cores A and B of magnetizable material. Core A is of the well known shell type, and comprises three legs 1, 2 and 3, connected in parallel to form a closed magnetic path with the middle leg 2 comprising a bridging member. The core B is of the ordinary closed core type. Periodic flux is supplied to the transformer T by a primary winding 4 linking the core B and leg 3 of core A. The primary winding 4 is constantly supplied with periodic current, and, as here shown, the source of this current is an alternating current generator G. The core B also carries a secondary or output winding 6

which may supply energy to any suitable output circuit. As here shown, the winding 6 is connected with a lamp 7.

For the purpose of controlling the electromotive force induced in winding 6, an input winding 9 is located on the middle leg 2 of core A, and current is at times supplied to this winding to vary the permeability of core A. It is preferable, though not essential, to supply the winding 9 with unidirectional current, and for this purpose the winding is provided with a circuit including a battery 10 and a switch 11. It should be pointed out, however, that if the source of controlling current delivers alternating current, a rectifier may be included in circuit with winding 9.

The bridging member 2 of core A also carries a bias winding 9¹, which is constantly supplied with unidirectional current from a battery 8 in such direction that the fluxes created in core A by currents in windings 9 and 9¹ are in opposition.

The parts are so proportioned that when no current is supplied to the input winding 9, the flux created in core A by current in the bias winding 9¹ decreases the permeability of this core to such an extent that a large proportion of the flux created by current in the primary winding 4 is forced into core B, thereby inducing in secondary winding 6, an electromotive force sufficiently high to energize the load 7. When the switch 11 is closed, however, so that current is supplied to the input circuit including winding 9, the flux created by current in this winding opposes the flux created by current in the bias winding 9¹, thereby increasing the permeability of core A, and allowing a larger proportion of the flux from primary winding 4 to thread core A. The result of this change is to decrease the flux in core B, and hence to decrease the electromotive force induced in winding 6. It follows, therefore, that when current is supplied to the input winding 9, the electromotive force supplied to the load is decreased, and by properly proportioning the parts the amount of energy supplied to the load when the input circuit is energized may be adjusted to a value which is insufficient to energize the device connected with the out-

put circuit. The apparatus shown in Fig. 1, therefore, functions to discontinue the operation of the controlled device in response to current in the input circuit, and, therefore, corresponds to the control of a load by the "back contact" of a relay of the ordinary type, which back contact is opened when the relay is energized to discontinue the supply of current to the load controlled thereby.

Referring now to Figs. 2 and 3, I have arranged the two cores A and B similar to the cores shown in Fig. 1, in parallel planes. The primary winding is made in two coils 4^a and 4^b, each of which links core B and an end leg of core A. The two coils 4^a and 4^b of the primary winding are connected in parallel across the generator G. The secondary winding is also formed in two coils 6^a and 6^b located respectively on the legs 1 and 3 of core A. The load 7 is connected with the coils 6^a and 6^b in parallel, the secondary coils being so arranged that their electromotive forces are in opposition, but aid in supplying current to the load 7. The input winding 9 is located on the middle leg 2 of core A, as in Fig. 1, but with this form of apparatus no bias winding is required. As shown in Fig. 3, current is supplied to the input circuit including winding 9 from a secondary of a transformer 12 through a rectifier 13. The primary of transformer 12 may receive energy from any suitable source of alternating current through the switch 11.

When switch 11 is open, as shown in the drawings, the permeability of core A is comparatively high and the proportion of flux from the coils 4^a and 4^b of the primary winding which threads core A is then sufficiently high to energize the load 7. When switch 11 is closed, however, to supply current to the input winding 9, the unidirectional flux thus set up in the core A decreases the permeability of this core, thereby forcing a larger proportion of the primary flux into core B and decreasing the electromotive force induced in the coils 6^a and 6^b of the secondary winding. The result is a decrease in the electromotive force applied to the load 7.

Referring now to Fig. 4, the apparatus here shown is similar to the apparatus illustrated in Figs. 2 and 3, except that the core B is a shell type core having three legs 14, 15 and 16. The end legs 14 and 16 thread the coils 4^a and 4^b respectively of the primary winding, and the middle leg 15 of core B is provided with a winding 17 which is at times supplied with current through a rectifier R from the coils 6^a and 6^b of the secondary winding. As here shown, portions of the coils 6^a and 6^b are tapped to supply current to the load 7, and other taps of these two coils are used to supply current through the rectifier R to winding 17. When no current is being supplied to the input winding 9 the electromotive force induced in coils 6^a and 6^b is comparatively high,

so that the load 7 is energized. Furthermore, this comparatively high electromotive force causes a comparatively high current in winding 17 on the middle leg 15 of core B. The current in winding 17 maintains the permeability of core B at a comparatively low value, thus forcing a large proportion of the primary flux through core A. When current is supplied to the input winding 9, however, the permeability of core A is decreased, as explained in connection with Figs. 2 and 3. This change in the permeability of core A decreases the electromotive force induced in the secondary coils 6^a and 6^b and diminishes the current supplied to the load 7. Furthermore, the decrease in secondary induced electromotive force decreases the current supplied to winding 17 and allows the permeability of core B to rise to a comparatively high value. It will be seen, therefore, that winding 17 assists winding 9 in decreasing the primary flux in core A and increasing the primary flux in core B. Both of these effects decrease the electromotive force induced in the coils 6^a and 6^b of the secondary winding, and it will therefore be seen that the winding 17 is a regenerative winding.

The operation of the apparatus shown in Fig. 4 may be improved under some circumstances by including in series with the load 7 a winding the impedance of which varies in accordance with the electromotive force delivered by the secondary winding. This modification is illustrated in Fig. 5, in which the transformer T, in addition to cores A and B, comprises also a shell type core C comprising three legs 18, 19 and 20. The middle leg 19 of this core C links winding 17, which is supplied with current from the secondary coils 6^a and 6^b through rectifier R as in Fig. 4. The end legs 18 and 20 of core C carry windings 21^a and 21^b respectively, which are connected in parallel and interposed between the load 7 and the secondary coils 6^a and 6^b.

When no current is being supplied to the input circuit, a comparatively large proportion of the primary flux supplied by primary coils 4^a and 4^b threads core A and induces a comparatively high electromotive force in the secondary winding comprising coils 6^a and 6^b. This electromotive force supplies current to the load 7 and also to winding 17, thereby maintaining at a comparatively low value the permeabilities of cores B and C. Under these conditions, then, the impedances of windings 21^a and 21^b are comparatively low. When current is supplied to the primary winding 9, however, the resulting decrease in the permeability of core A forces some of the primary flux normally threading this core into core B. The electromotive force induced in the coils 6^a and 6^b of the secondary winding is therefore decreased. This decrease in the secondary induced electromotive force decreases the current in winding

17 and increases the permeabilities of both cores B and C. The decreased permeability of core B shunts still more of the primary flux away from core A, and hence still further decreases the secondary induced electromotive force. The increased permeability of core C increases the impedances of windings 21^a and 21^b, and the effect is therefore to increase the impedance in series with the load 7.

It will be plain, therefore, that the apparatus shown in Fig. 5 operates to decrease the current supplied to the load in response to current supplied to the input circuit by two effects: First, a decrease in the secondary induced electromotive force, and, second, an increase in the impedance in series with the load.

In connection with Figs. 3, 4 and 5, it should be particularly pointed out, that while I have for purposes of explanation, shown two alternating current coils 4^a and 4^b, and have connected these coils in parallel, this particular number and arrangement of windings is not essential.

In the modified form of apparatus shown in Fig. 6, the same principles are employed as have been discussed in connection with Fig. 5, but the arrangement of the parts is slightly different. In Fig. 6 cores A and B are located in the same plane, and a single primary winding 4 embraces leg 3 of core A and leg 16 of core B. A single secondary winding 6 is located on leg 3 of core A and supplies current to the load 7 in series with winding 21 on leg 20 of core C. The core C may be conveniently disposed in parallel relation with core B, and winding 17 links both leg 15 of core B and leg 19 of core C. This winding 17 is connected, through rectifier R, across a portion of the secondary winding 6 and operates in the same manner as explained in connection with Fig. 5. The input winding 9 is located on the middle leg 2 of core A as in the preceding figures. It will be manifest from an inspection of the drawings, that the principal differences between Figs. 5 and 6 are in the arrangement of the core and in the fact that only one coil is used in each of the primary windings 4, the secondary winding 6, and the load impedance 21. With this arrangement there is, of course, no balancing effect between matched coils on opposite legs of the cores, and in order to prevent the passage of alternating flux through the middle legs of the cores I provide conducting sleeves on these middle legs. Thus a sleeve 25 is located on the middle leg 2 of core A to prevent the passage of alternating fluxes through this leg and the input winding 9 located thereon. In similar manner, and for a similar purpose, a sleeve 26 is located on the middle leg 15 of core B and a sleeve 27 is located on the middle leg 19 of core C. The operation of the apparatus shown in Fig. 6 is identical with the operation of the apparatus shown in Fig. 5,

and will be understood from the foregoing without further explanation.

Another embodiment of my invention is shown in Fig. 7, in which the three cores A, B and C are all supplied with primary flux. In this particular form a single primary winding 4 connected with the generator G embraces the end legs 3, 16 and 20 of cores A, B and C, respectively. The secondary winding is made up of a coil 6^a located on leg 3 of core A and a coil 6^b located on leg 16 of core B and connected in series opposition with the load 7. The input winding 9 is located on the middle leg 2 of core A and this leg is also provided with a conducting sleeve 25 to prevent the linkage of winding 9 by alternating primary flux. The middle leg 19 of core C carries a winding 17 which is connected, through rectifier R and in parallel with the load 7, across the coils 6^a and 6^b of the secondary winding. A sleeve 27 of conducting material located on the leg 19 of core C prevents the passage of primary flux through winding 17. The middle leg 15 of core B is provided with a bias winding 32 constantly supplied with unidirectional current from a battery 33 and the linkage of primary flux with this winding is prevented by a sleeve 26.

When no current is being supplied to the input winding 9 the permeability of core A is comparatively high, and the parts are so proportioned that under these conditions the electromotive force induced in coil 6^a predominates over the electromotive force induced in coil 6^b and operates to supply current to the load 7. The electromotive force applied to the load is also rectified and applied to the winding 17 and serves to maintain the permeability of core C at a comparatively low value. The distribution of primary flux between the three cores may be regulated to a proper value to achieve the results described by properly choosing the dimensions of the parts and the amount of the biasing flux supplied by winding 32.

When current is supplied to the input winding 9, the permeability of core A is decreased and the primary flux through core B is increased. Both of these changes cause the electromotive forces induced in coils 6^a and 6^b to become more nearly equal, and tend to decrease the electromotive force supplied to the load. This decrease in the electromotive force also decreases the current supplied to winding 17 and increases the permeability of core C, thereby allowing a greater proportion of the primary flux to thread core C and still further decreasing the electromotive force supplied across the load.

It should be pointed out that the bias winding 32 is not essential, but that the apparatus can be constructed to operate satisfactorily by properly choosing the dimensions of the cores. If the bias winding 32 is omitted, the

core B may, of course, be formed as a simple closed core, without the middle leg 15.

The core C with its control winding 17 has an important function in making the apparatus largely insensitive to variations in the electromotive force applied to the primary winding 4. Since the output current supplied to load 7 is zero when the electromotive forces induced in coils 6^a and 6^b are exactly balanced, there can be no variation of the output current in response to variations of the electromotive force applied to the primary winding 4 when the output current is zero. Furthermore, when the output current is comparatively low but not exactly zero, a large proportion of the primary flux links core C and hence cannot affect the electromotive force delivered to the load. It follows that for a wide range of inputs, the resulting variation in current supplied to the load may be held within comparatively small limits.

Referring now to Fig. 8, in this modification, cores A and C are disposed in the same plane with their legs 3 and 20 adjacent and parallel. Core B is disposed at right angles with cores A and C and has its leg 16 linked by the primary winding 4 which also links leg 3 of core A and leg 20 of core C. The secondary winding 6 is disposed at right angles with winding 4 and links leg 3 of core A and leg 16 of core B. The input winding 9 and sleeve 25 are located on the middle leg 2 of core A, as in Fig. 7, and winding 17 and sleeve 27 are located on the middle leg 19 of core C. Furthermore, the middle leg 15 of core B carries a sleeve 26 and a bias winding 32 supplied with current from battery 33 in the same manner and for the same purpose as have been previously described in connection with Fig. 7. The secondary winding 6 is connected directly with the load 7, and winding 17 is connected, through rectifier R, with secondary winding 6, in parallel with the load 7.

The primary winding 4 supplies flux to all three cores A, B and C, and, due to the angular disposition of the cores and windings, the flux in core A opposes the flux in core B in so far as the effects of these fluxes upon secondary 6 are concerned. For example, at an instant when current in winding 4 induces flux flowing from top to bottom of leg 3 of core A, the flux induced in leg 16 of core B flows toward the observer at right angles to the plane of the paper, and it is obvious that these fluxes in legs 16 and 3 will induce opposing electromotive forces in secondary 6. The parts are so proportioned that when no current is supplied to the input winding 9, a substantial portion of this primary flux threads core A. Under these conditions the flux in core A predominates over the opposing flux in core B and induces in secondary 6 a resultant electromotive force which en-

ergizes the load 7 and also maintains the permeability of core C at a comparatively low value. It will be apparent that the leg 3 of core A and leg 16 of core B are threaded by primary flux which traverses the winding 6 in opposite directions at an instant so that the voltages induced by fluxes in these members are opposed in winding 6. When current is supplied to the input winding 9, the permeability of core A is decreased, and an increased proportion of the primary flux threads core B. The primary flux in leg 16 of core B induces in secondary 6 an electromotive force which opposes the electromotive force induced in this winding by flux in leg 3 of core A, and the net effect is a decrease in the secondary induced electromotive force. This decreased electromotive force diminishes the current supplied to the load 7, and also decreases the current supplied to winding 17 on core C. The consequent increase in the permeability of core C allows an increased proportion of the primary flux to link leg 20 of core C and still further decreases the current supplied to the load.

The core C also serves to compensate for variations in the electromotive force applied to the primary winding 4 in the same manner as described in connection with Fig. 7.

It should be pointed out that the forms of apparatus shown in Figs. 2 to 6, inclusive, do not utilize a bias winding of any form, and, therefore, do not possess saturation characteristics. That is to say, the current supplied to the load continues to decrease for any increase in the current supplied to the input winding however large. In certain of the other modifications of my invention, however, such for example, as the form shown in Fig. 1, an increase of input current causes a decrease in the output current until the effect of the input equals the effect of the bias, and any subsequent increase in the input will again cause the output to increase.

Particular attention should be directed to the fact that although apparatus embodying my invention operates most satisfactorily with input currents which are unidirectional in character, the apparatus may be made to function with alternating input currents or with pulsating unidirectional input currents the frequency or periodicity of which is different from the frequency of the current supplied to the primary winding.

Attention should also be directed to the fact that a conducting sleeve similar to that shown at 26 in Fig. 6 may be employed with the device shown in Fig. 1 to prevent the flow of alternating current in the bias or input windings. This function is performed, in the modification shown in Figs. 2 to 5 inclusive, by arranging the magnetizing force so that there is no alternating magnetic potential drop across the leg which carries the direct current winding.

Although I have herein shown and described only a few forms of apparatus embodying my invention, it is understood that various changes and modifications may be made therein within the scope of the appended claims without departing from the spirit and scope of my invention.

Having thus described my invention, what I claim is:

1. In combination, a primary winding supplied with periodic current, a secondary winding inductively related with said primary winding, a load connected with said secondary winding, a magnetizable core linking at least one of said windings, a source of control current, and a third winding on said core at times connected with said source and arranged when supplied with current to decrease the coupling between said primary and secondary windings.

2. In combination, a primary winding supplied with periodic current, a secondary winding inductively related with said primary winding, a load connected with said secondary winding, a magnetizable core linking at least one of said windings, means for supplying a substantially constant flux to said core, a source of control current, and a third winding on said core at times connected with said source and arranged when supplied with current to oppose the flux supplied by said means.

3. In combination, two magnetizable cores, a primary winding supplied with periodic current and linking both said cores, a secondary winding linking one only of said cores, a source of control current, and a third winding on one core at times connected with said source and arranged when supplied with current to vary the permeability of the associated core in such manner as to decrease the flux from said primary winding which links said secondary winding.

4. In combination, two magnetizable cores, a primary winding supplied with periodic current and linking both said cores, a secondary winding linking one only of said cores, a source of control current, and a third winding on one of said cores at times connected with said source and arranged when supplied with current to decrease the relative permeability of the core linking said secondary winding and operating to reduce the electromotive force induced in such secondary winding.

5. In combination, a primary winding supplied with periodic current, a secondary winding, a shell type core having an end leg linking both said windings, a second core linking said primary winding but not said secondary winding, and a third winding located on the middle leg of said shell type core, and operating when supplied with current to decrease the electromotive force induced in said secondary winding.

6. In combination, a primary winding supplied with periodic current, a secondary winding, a shell type core having an end leg linking both said windings, a second core linking said primary winding but not said secondary winding, a third winding located on the middle leg of said shell type core and operating when supplied with unidirectional current to decrease the permeability of such shell type core to flux from said primary winding, and a sleeve of conducting material located on the middle leg of said shell type core.

7. In combination, a first closed magnetizable core having a bridging member, two primary windings located on said first core and supplied in parallel with periodic current in such manner that the fluxes produced thereby are in opposition in said bridging member, a load, two secondary windings on said first core connected in parallel across said load in such manner that the electromotive forces induced in such secondary windings are additive in said load, a second magnetizable core linking both said primary windings, and an input winding located on said bridging member and operating when supplied with current to decrease the electromotive forces induced in said secondary windings.

8. In combination, a primary winding supplied with periodic current, two magnetizable cores each linking said primary winding, a secondary winding located on one said core, means for varying the permeability of such one core to change the electromotive force induced in said secondary winding, and means for controlling the permeability of the other core in accordance with the electromotive force induced in said secondary winding.

9. In combination, a primary winding supplied with periodic current, two magnetizable cores each linking said primary winding, a secondary winding located on one said core, means for supplying a unidirectional flux to such one core to vary the electromotive force induced in said secondary winding, and means for producing in the other said core a unidirectional flux the magnitude of which depends upon the magnitude of the electromotive force induced in said secondary winding.

10. In combination, two magnetizable cores, each having a bridging member, a primary winding linking both said cores and supplied with periodic current, a secondary winding linking one of said cores but not the other, a third winding located on the bridging member of said one core and operating when supplied with current to decrease the permeability of said one core, and a fourth winding located on the bridging member of said other core and receiving energy from said secondary winding.

11. In combination, two magnetizable

cores, each having a bridging member, a primary winding linking both said cores and supplied with periodic current, a secondary winding linking one of said cores but not the other, a third winding located on the bridging member of said one core and operating when supplied with current to decrease the permeability of said one core, a fourth winding located on the bridging member of said other core, and means including a rectifier for connecting said fourth winding with at least a portion of said secondary winding.

12. In combination, two magnetizable cores, each having a bridging member, a source of periodic current, two primary windings each linking both said cores and connected in parallel across said source, a load, two secondary windings each linking one said core but not the other and having at least a portion of their windings connected in parallel across said load, an input winding located on the bridging member of said one core and operating when supplied with current to decrease the permeability of such one core, an additional winding located on the bridging member of said other core, and means including a rectifier for connecting said additional winding across portions of both said secondary windings in parallel.

13. In combination, a primary winding supplied with periodic current, two magnetizable cores each linking said primary winding, a secondary winding linking one of said cores but not the other, means for varying the relative permeability of said cores, an additional winding, means for varying the impedance of said additional winding in response to variations in the electromotive force induced in said secondary winding, a load, and means including said additional winding for connecting said load with said secondary winding.

14. In combination, a primary winding supplied with periodic current, a secondary winding inductively related to said primary windings, means for varying the coupling between said primary and secondary windings, a third winding, means for varying the impedance of said third winding in response to variations in the electromotive force induced in said secondary winding, and a load connected with said secondary winding in circuit with said third winding.

15. In combination, a primary winding supplied with periodic current, a secondary winding inductively related to said primary windings, means for varying the coupling between said primary and secondary windings, a third winding, a magnetizable core linking said third winding, means for varying the permeability of said core in accordance with the electromotive force induced in said secondary winding, and a load connected with said secondary winding in circuit with said third winding.

16. In combination, two magnetizable cores, a primary winding supplied with periodic current and linking both said cores, a secondary winding linking one only of said cores, means for at times varying the relative permeabilities of said cores to decrease the electromotive force induced in said secondary winding, a third winding, a third magnetizable core linking said third winding, means responsive to a decrease in the electromotive force induced in said secondary winding to increase the permeability of said third core, and a load connected with said secondary winding in series with said third winding.

17. In combination, two magnetizable cores, a primary winding supplied with periodic current and linking both said cores, a secondary winding linking one only of said cores, means for at times varying the relative permeabilities of said cores to decrease the electromotive force induced in said secondary winding, a third winding, a third magnetizable core linking said third winding, a fourth winding on said third core, means including a rectifier for connecting said fourth winding with said secondary winding, and a load connected with said secondary winding in series with said third winding.

18. In combination, two magnetizable cores, a primary winding supplied with periodic current and linking both said cores, a secondary winding linking one core but not the other, means for varying the permeability of one said core to change the electromotive force induced in said secondary winding, a third winding, a third magnetizable core linking said third winding, a fourth winding linking said third core and said other core, means including a rectifier for supplying energy from said secondary winding to said fourth winding, and a load connected with said secondary winding in series with said third winding.

19. In combination, three magnetizable shell type cores, a primary winding supplied with periodic current and linking an end leg each of a first and a second of said cores, a secondary winding linking an end leg of said first core, three conducting sleeves one located on the middle leg of each said core, a third winding on the middle leg of said first core and operating when supplied with current to vary the permeability of such core, a fourth winding linking the middle legs of the second and third cores, means including a rectifier for supplying energy from said secondary winding to said fourth winding, a fifth winding on an end leg of said third core, and a load connected with said secondary winding in series with said fifth winding.

20. In combination, three magnetizable cores, a source of periodic current, means receiving energy from said source for cre-

ating periodic fluxes in each said core, means for controlling the distribution of such periodic fluxes between said three cores, two secondary windings located on two of said cores respectively, a load connected with said two secondary windings in series opposition, and an additional winding located on the remaining core and connected in parallel with said load.

21. In combination, three magnetizable cores, a source of periodic current, means receiving energy from said source for creating periodic fluxes in each said core, an input winding located on one said core and operating when supplied with current to vary the permeability of such one core, a first secondary winding located on such one core, a second secondary winding located on another core, a load connected with said two secondaries in series opposition, an additional winding located on the remaining core, and means including a rectifier for connecting said additional winding in parallel with said load.

22. In combination, three magnetizable cores, a primary winding supplied with periodic current and linking all said cores, a load, secondary means inductively related with two of said cores for delivering to said load an electromotive force which depends upon the relative value of the fluxes in such two cores, an input winding located on one of said two cores and operating when supplied with current to vary the permeability of said one core, and means for controlling the permeability of the third core in accordance with the electromotive force applied to said load.

23. In combination, three magnetizable cores, a primary winding supplied with periodic current and linking all said cores, two secondary windings located respectively on a first and a second of said cores, a load connected with said two secondaries in series opposition, an input winding operating when supplied with current to vary the permeability of said first core, a bias winding supplied with current and located on said second core, and an additional winding located on the third core and connected in parallel with said load.

24. In combination, a primary winding supplied with periodic current, a secondary winding, two magnetizable cores each linking both said windings in such manner that the fluxes produced in said two cores by current in said primary winding flow in opposite directions through the secondary winding, an input winding on one said core operating when supplied with current to vary the relative permeability of said two cores, a third core linking said primary winding but not said secondary winding, a load connected with said secondary winding, and an

additional winding on said third core connected with said secondary winding.

25. In combination, a primary winding supplied with periodic current, a secondary winding, two magnetizable cores each linking both said windings in such manner that the fluxes produced in said two cores by current in said primary winding flow in opposite directions through the secondary winding, an input winding on one said core operating when supplied with current to vary the relative permeability of said two cores, a bias winding on the other said core supplied with unidirectional current, a third core linking said primary winding but not said secondary winding, a load connected with said secondary winding, an additional winding on said third core, and means including a rectifier for connecting said additional winding with said secondary winding in parallel with said load.

In testimony whereof I affix my signature.
PHILIP H. DOWLING.