E. F. W. ALEXANDERSON.

MEANS FOR CONTROLLING ALTERNATING CURRENTS.

APPLICATION FILED APR. 11, 1918.

**1,334,126.** Patented Mar. 16, 1920.

Fig. 1.

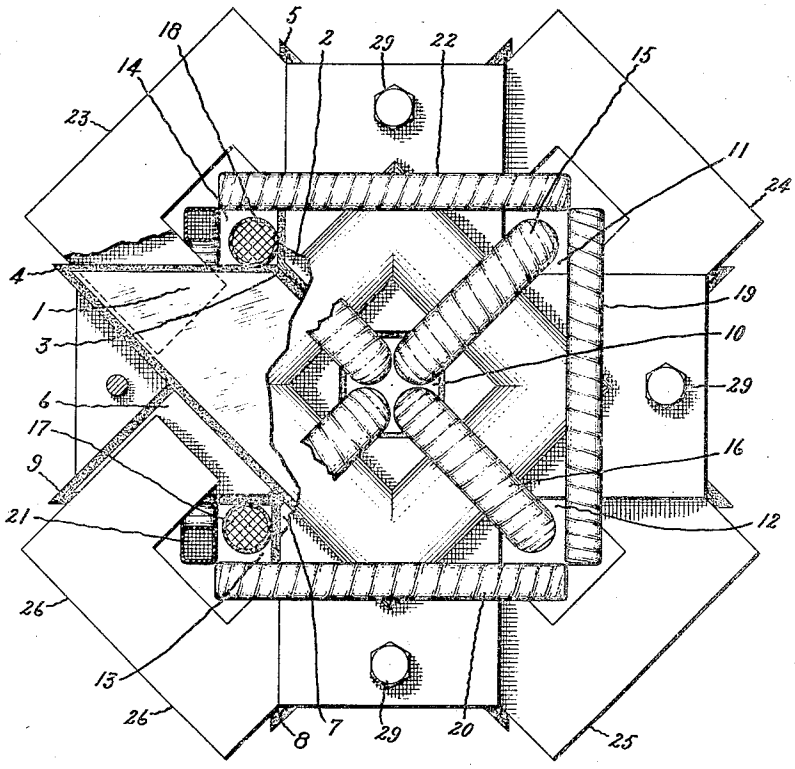
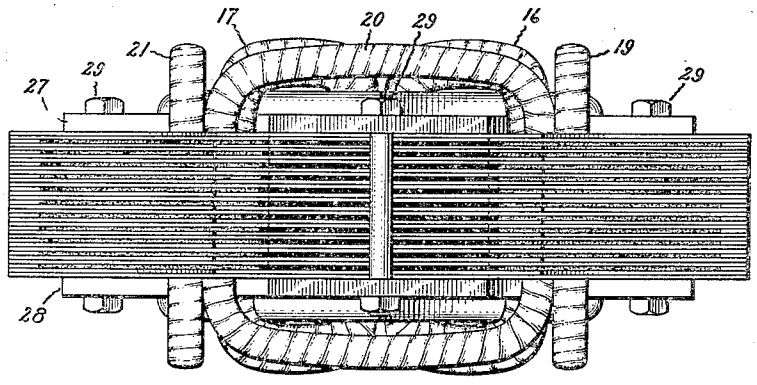



Fig. 2.




Inventor:
Ernst F. W. Alexanderson,
by Albert G. Davis
His Attorney.

# UNITED STATES PATENT OFFICE.

ERNST F. W. ALEXANDERSON, OF SCHENECTADY, NEW YORK, ASSIGNOR TO GENERAL ELECTRIC COMPANY, A CORPORATION OF NEW YORK.

## MEANS FOR CONTROLLING ALTERNATING CURRENTS.

1,334,126. Specification of Letters Patent. Patented Mar. 16, 1920.

Application filed April 11, 1918. Serial No. 227,946.

*To all whom it may concern:*

Be it known that I, ERNST F. W. ALEXANDERSON, a citizen of the United States, residing at Schenectady, county of Schenectady, State of New York, have invented certain new and useful Improvements in Means for Controlling Alternating Currents, of which the following is a specification.

My present invention relates to electromagnetic apparatus for use with high frequency alternating currents, either for controlling the flow of such currents in a circuit, for multiplying the frequency thereof, or for similar purposes. More particularly my invention relates to electromagnetic apparatus of a kind which I term magnetic amplifiers such, for example, as are described in my prior patent #1,206,643.

The object of my invention is to improve the construction of magnetic amplifiers of the class described in my prior patent in order to render them more efficient for the purpose for which they may be employed. In the construction of these devices it is desirable that the magnetic circuits and the windings be so arranged that no high frequency current will flow in the circuit which supplies the controlling current. Where separate windings are employed for the high frequency current and the controlling current, this result may be accomplished in either of two general ways: First, the controlling winding may be made inductively independent of the high frequency winding; second, the windings may be so arranged that one-half of the controlling winding is interlinked with the high frequency flux in one direction and the other half is interlinked with the high frequency flux in the opposite direction so that the induced potentials are neutralized in the winding itself. In my present invention the desired result is accomplished in the first way mentioned.

The features of my invention which I consider novel are pointed out with particularity in the appended claims. The invention itself, however, together with further objects and advantages, will best be understood by reference to the following description taken in connection with the accompanying drawing in which Figure 1 shows a plan view of one of my improved devices with certain portions broken away, and Fig. 2 shows an elevation.

As indicated in the drawing, the magnetic core is built up of a large number of thin laminations of magnetic material separated by sheets of insulating material. The top layer as shown in Fig. 1 consists of two sheets 1 and 2 of magnetic material of trapezoidal shape with the tops of the trapezoids adjacent each other but separated by an air gap 3. This layer is separated from the next layer by sheets of insulating material 4, 5, of slightly larger area than the sheets 1 and 2 so that the edges of these sheets project beyond those of the sheets 1 and 2. The second layer is made up of two similar sheets 6, 7 of magnetic material of the same shape and size as the sheets 1 and 2 but placed at right angles to the sheets 1 and 2. The second layer is separated from the third layer by the sheets 8 and 9 of insulating material which are arranged relatively to the sheets 7 and 8 in the same manner that the sheets 4 and 5 are arranged relatively to sheets 1 and 2. The third layer is made up and arranged in the same manner as the first layer and the fourth layer in the same manner as the second layer. The laminations are built up in this way until the desired thickness of the magnetic structure is obtained. I find that it is important that the sheets of insulating material shall be larger than the sheets of magnetic material in order that there is no possibility of the edges of the magnetic sheets coming in contact with one another. Each of the sheets is provided with a triangular notch in its top and these notches register with one another to form a square opening 10 through the center of the core structure. Opposite non-parallel sides of the trapezoidal sheets also form four openings or notches 11, 12, 13 and 14 and the coils 15, 16, 17 and 18 which carry the high frequency current are placed in the openings 10, 11, 12, 13 and 14, as indicated. These windings are so arranged that the high frequency flux will circulate through the core around the opening 10. The coils 19, 20, 21 and 22

which carry the controlling current are also located in the openings 11, 12, 13 and 14, as indicated. The magnetic circuits for the controlling flux are completed by means of U-shaped sheets 23, 24, 25 and 26 which are inserted between the trapezoidal-shaped sheets as indicated. These U-shaped sheets form yokes which may be removed and thus allow the coils carrying the controlling current to be removed independently of the high frequency coils. It will be apparent that each of the controlling coils 19, 20, 21 and 22 will produce a flux in two complete magnetic circuits. For example, the coil 21 will produce a flux through the U-shaped sheets 23 and the portion of the core embraced by the high frequency coil 18. It will also produce a flux through the U-shaped sheets 26 and the portion of the core embraced by the high frequency coil 17. Thus the controlling flux will be effective in the part of the magnetic structure which is traversed by the high frequency flux but none of the high frequency flux will pass through the U-shaped sheets and no high frequency currents will be induced in the controlling windings. In other words, the controlling windings are in non-inductive relation to the high frequency windings and each of the magnetic circuits for the controlling flux are partly coincident with and partly separate from the magnetic circuit for the high frequency flux.

It will be noted that the high frequency magnetic circuit comprises four portions at the air gaps 3 which are of much smaller cross section than the other portions. This feature is of advantage in a device of the type here involved as the portions of smaller cross section determine the saturation of the core and the portions of larger cross section tend to reduce the magnetizing current when the core is not saturated, thus artificially increasing the range of permeability of the combined structure. Each of the magnetic circuits for the controlling fluxes includes one of these portions of the magnetic circuit for the high frequency flux of relatively small cross section.

When a sufficient number of laminations are piled on top of one another the mass is secured by means of the clamping plates 27 and 28 which are held together by means of bolts 29.

The magnetic material used should be of such a nature and in such thin sheets that its permeability is substantially independent of the frequency of the magnetizing current at the radio frequency at which it is operated. I have found in practice that the sheets should preferably be two mils or less in thickness.

While I have illustrated and described a single way of carrying my invention into effect, it is apparent that many modifications may be made in the structural details without departing from the scope of the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States, is,—

1. Means for controlling the flow of radio frequency current comprising a magnetic core made up of a plurality of thin sheets of magnetic material separated by sheets of insulating material, the area of the sheets of insulating material being greater than the area of the sheets of magnetic material so that their edges project beyond those of the sheets of magnetic material, the sheets of magnetic material being so arranged that certain portions of the core have a much smaller cross sectional area than other portions and the magnetic material being of such a nature and in such thin sheets that its permeability is substantially independent of the frequency of the magnetizing current at ordinary radio frequencies.

2. An apparatus of the class described comprising a magnetic core made up of a plurality of thin sheets of magnetic material separated by sheets of insulating material, the area of the sheets of insulating material being greater than the area of the sheets of magnetic material so that their edges project beyond those of the sheets of magnetic material and the magnetic material being of such a nature and in such thin sheets that its permeability is substantially independent of the frequency of the magnetizing current at ordinary radio frequencies.

3. An apparatus of the class described comprising a magnetic core made up of a plurality of layers of magnetic material separated by sheets of insulating material, each layer of magnetic material being made up of two similar sheets of magnetic material of trapezoidal shape with the tops of said trapezoids adjacent each other but separated by an air gap, the sheets of every alternate layer being arranged at a right angle to the sheets of every other layer and registering notches in the top of each trapezoidal sheet whereby a central opening is formed in the core.

4. An apparatus of the class described comprising a magnetic core made up of a plurality of layers of magnetic material separated by sheets of insulating material, each layer of magnetic material being made up of two similar sheets of magnetic material of trapezoidal shape with the tops of said trapezoids adjacent each other but separated by an air gap, whereby notches are formed between the adjacent non-parallel sides of the trapezoidal sheets of each layer, the sheets of every alternate layer being arranged at a right angle to the sheets of the

other layers and registering notches in the top of each trapezoidal sheet whereby a central opening is formed in the core.

5. An apparatus of the class described comprising a magnetic core made up of a plurality of layers of magnetic material separated by sheets of insulating material, each layer of magnetic material being made up of two similar sheets of magnetic material of trapezoidal shape with the tops of said trapezoids adjacent each other, whereby notches are formed between the adjacent non-parallel sides of the trapezoidal sheets of each layer, the sheets of every alternate layer being arranged at a right angle to the sheets of every other layer, registering notches in the top of each trapezoidal sheet whereby a central opening is formed in the core, and coils adapted to carry high frequency current located in said central opening and said notches so as to inclose portions of the magnetic core.

6. An apparatus of the class described comprising a magnetic core made up of a plurality of layers of magnetic material separated by sheets of insulating material, each layer of magnetic material being made up of two similar sheets of magnetic material of trapezoidal shape with the tops of said trapezoids adjacent each other, whereby notches are formed between the adjacent non-parallel sides of the trapezoidal sheets of each layer, the sheets of every alternate layer being arranged at a right angle to the sheets of every other layer, registering notches in the top of each trapezoidal sheet whereby a central opening is formed in the core, and U-shaped sheets of magnetic material inserted between the superimposed non-parallel sides of the trapezoidal sheets in such a way as to embrace the notches between the adjacent non-parallel sides of the trapezoidal sheets of each layer.

7. An apparatus of the class described comprising a magnetic core made up of a plurality of layers of magnetic material separated by sheets of insulating material, each layer of magnetic material being made up of two similar sheets of magnetic material of trapezodial shape with the tops of said trapezoids adjacent each other, whereby notches are formed between the adjacent non-parallel sides of the trapezoidal sheets of each layer, the sheets of every alternate layer being arranged at a right angle to the sheets of every other layer, registering notches in the top of each trapezoidal sheet whereby a central opening is formed in the core, coils adapted to carry a controlling current located in said notches and U-shaped sheets of magnetic material inserted between the superimposed non-parallel sides of the trapezoidal sheets in such a way as to embrace the notches between the adjacent non-parallel sides of the trapezoidal sheets of each layer, whereby magnetic circuits are completed for fluxes produced by controlling current in said coils.

8. An apparatus of the class described comprising a magnetic core made up of a plurality of layers of magnetic material separated by sheets of insulating material, each layer of magnetic material being made up of two similar sheets of magnetic material of trapezoidal shape with the tops of said trapezoids adjacent each other, whereby notches are formed between the adjacent non-parallel sides of the trapezoidal sheets of each layer, the sheets of every alternate layer being arranged at a right angle to the sheets of every other layer, registering notches in the top of each trapezoidal sheet whereby a central opening is formed in the core, coils adapted to carry high frequency current located in said central opening and said notches so as to inclose portions of the magnetic core, coils adapted to carry a controlling current located in said natches and U-shaped sheets of magnetic material inserted between the superimposed non-parallel sides of the trapezoidal sheets in such a way as to embrace the notches between the adjacent non-parallel sides of the trapezoidal sheets of each layer, whereby magnetic circuits are completed for fluxes produced by controlling current in said coils.

9. An apparatus of the class described comprising a magnetic core, a plurality of separate windings on said core adapted to carry high frequency current and a plurality of separate windings on said core adapted to carry a controlling current, the core being so constructed and the windings being so disposed thereon as to provide a single magnetic circuit for the fluxes produced by all of the high frequency windings and a plurality of magnetic circuits for the fluxes produced by the controlling windings, the controlling windings being in non-inductive relation to the high frequency windings and each of the magnetic circuits for the controlling fluxes including a portion of the magnetic circuit for the high frequency flux.

10. An apparatus of the class described comprising a magnetic core made up of a plurality of thin sheets of magnetic material separated by sheets of insulating material, the area of the sheets of insulating material being greater than the area of the sheets of magnetic material so that their edges project beyond those of the sheets of magnetic material, the magnetic material being of such a nature and in such thin sheets that its permeability is substantially independent of the frequency of the magnetizing current at ordinary radio frequencies, a set of windings arranged on said core and adapted to carry a high frequency current and a second set

of windings on said core adapted to carry a controlling current.

11. An apparatus of the class described comprising a magnetic core made up of a plurality of thin sheets of magnetic material separated by sheets of insulating material, the area of the sheets of insulating material being greater than the area of the sheets of magnetic material, so that their edges project beyond those of the sheets of magnetic material, the magnetic material being of such a nature and in such thin sheets that its permeability is substantially independent of the frequency of the magnetizing current at ordinary radio frequencies, a set of windings arranged on said core and adapted to carry a high frequency current and a second set of windings on said core adapted to carry a controlling current, the two sets of windings being in non-inductive relation to each other.

12. An apparatus of the class described comprising a magnetic core made up of a plurality of thin sheets of magnetic material separated by sheets of insulating material, the area of the sheets of insulating material being greater than the area of the sheets of magnetic material so that their edges project beyond those of the sheets of magnetic material, the sheets of magnetic material being so arranged that certain portions of the core have a smuch smaller cross sectional area than other portions, the magnetic material being of such a nature and in such thin sheets that its permeability is substantially independent of the frequency of the magnetizing current at ordinary radio frequencies, a set of windings arranged on said core and adapted to carry a high frequency current and a second set of windings on said core adapted to carry a controlling current.

13. An apparatus of the class described comprising a magnetic core, a plurality of separate windings on said core adapted to carry high frequency current and a plurality of separate windings on said core adapted to carry a controlling current, the core being so constructed and the windings being so disposed thereon as to provide a single magnetic circuit for the fluxes produced by all of the high frequency windings and a plurality of magnetic circuits for the fluxes produced by the controlling windings, the controlling windings being in non-inductive relation to the high frequency windings and each of the magnetic circuits for the controlling fluxes including a portion of the magnetic circuit for the high frequency flux, the controlling magnetic circuits being made up in part of removable yokes whereby the controlling windings may be removed independently of the high frequency windings.

14. An apparatus of the class described comprising a magnetic core, a plurality of separate windings on said core adapted to carry a high frequency current, and a plurality of separate windings on said core adapted to carry a controlling current, the core being so constructed and the windings being so disposed thereon as to provide a single magnetic circuit for the fluxes produced by all of the high frequency windings and a plurality of magnetic circuits for the fluxes produced by the controlling winding, the magnetic circuit for the high frequency flux having a plurality of portions of smaller cross sectional area than other portions and each of the magnetic circuits for the controlling fluxes including one of the portions of the magnetic circuit for the high frequency flux of relatively small cross section.

15. An apparatus of the class described comprising a magnetic core, a plurality of separate windings on said core adapted to carry a high frequency current, and a plurality of separate windings on said core adapted to carry a controlling current, the core being so constructed and the windings being so disposed thereon as to provide a single magnetic circuit for the fluxes produced by all of the high frequency windings and a plurality of magnetic circuits for the fluxes produced by the controlling winding which are entirely independent of one another, the magnetic circuit for the high frequency flux having a plurality of portions of smaller cross sectional area than other portions and each of the magnetic circuits for the controlling fluxes including one of the portions of the magnetic circuit for the high frequency flux of relatively small cross section.

16. An apparatus of the class described comprising a magnetic core, a plurality of separate windings on said core adapted to carry a high frequency current, and a plurality of separate windings on said core adapted to carry a controlling current, the core being so constructed and the windings being so disposed thereon as to provide a single magnetic circuit for the fluxes produced by all of the high frequency windings and a plurality of magnetic circuits for the fluxes produced by the controlling winding, the magnetic circuit for the high frequency flux having a plurality of portions of smaller cross sectional area than other portions and each of th magnetic circuits for the controlling fluxes including one of the portions of the magnetic circuit for the high frequency flux of relatively small cross section, the controlling windings being non-inductively related to the high frequency windings.

17. An apparatus of the class described comprising a magnetic core, a plurality of separate windings on said core adapted to carry high frequency current and a plural-

ity of separate windings on said core adapted to carry a controlling current, the core being so constructed and the windings being so disposed thereon as to provide a single magnetic circuit for the fluxes produced by all of the high frequency windings and a plurality of magnetic circuits for the fluxes produced by the controlling windings, the controlling windings being in non-inductive relation to the high frequency windings and each of the magnetic circuits for the controlling fluxes being partly coincident with and partly separate from the magnetic circuit for the high frequency flux.

In witness whereof, I have hereunto set my hand this 10th day of April, 1918.

ERNST F. W. ALEXANDERSON.