March 12, 1957 E. G. COOK 2,785,226

BINAURAL SOUND REPRODUCTION

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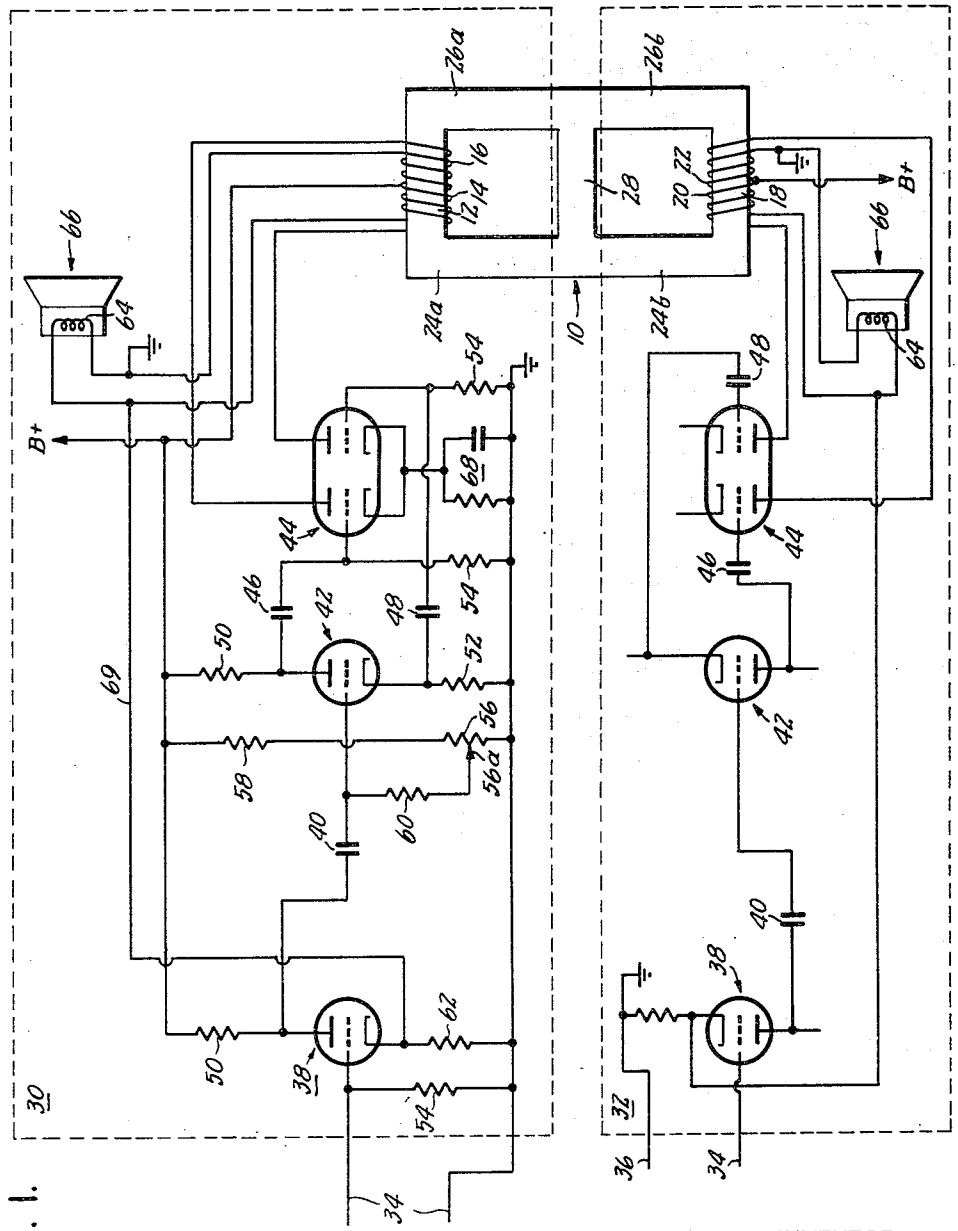


FIG. 1.

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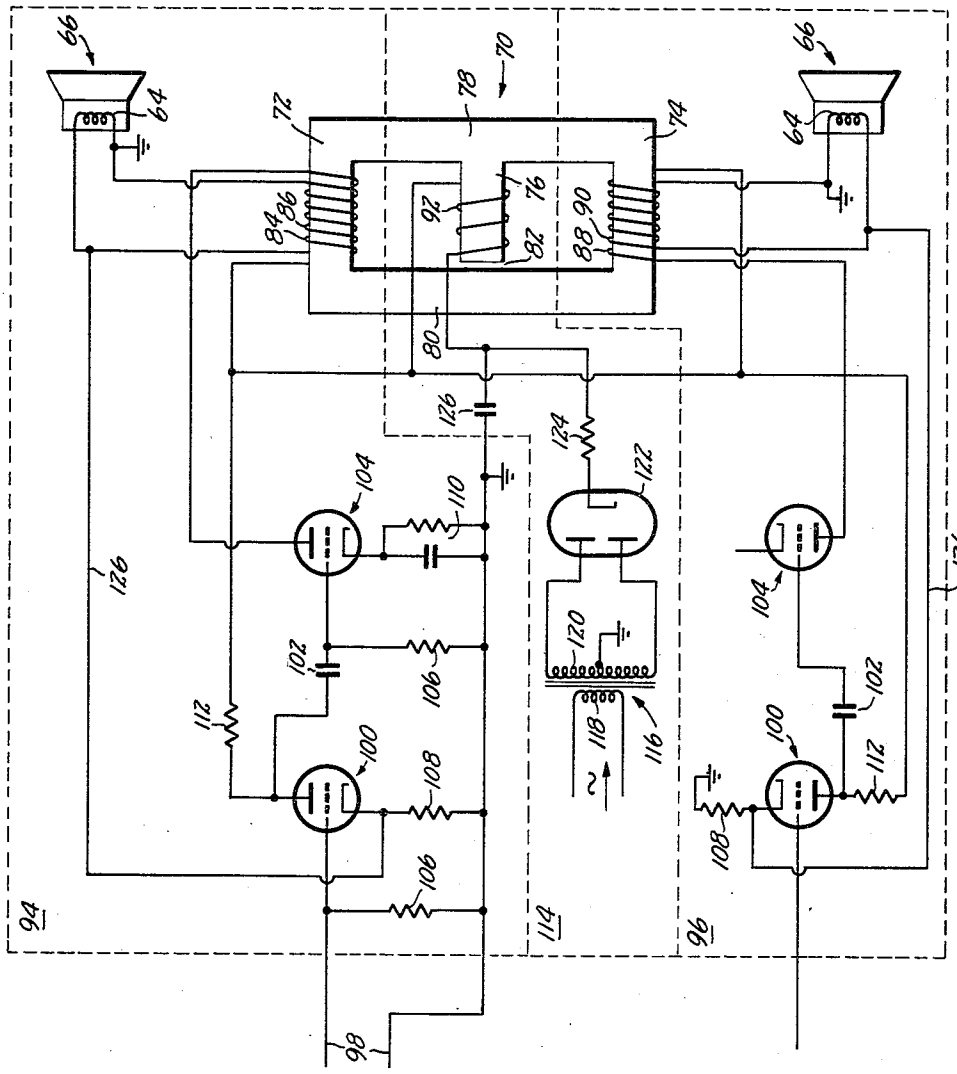


FIG. 2.

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BINAURAL SOUND REPRODUCTION

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10 Claims. (Cl. 179—1)

This invention relates to improvements in sound reproduction systems, and particularly to a sound reproducing system of the so-called binaural type.

In a binaural sound system of the type with which the present invention is concerned, sound waves are reproduced from electrical signals derived from two substantially identical sound recordings. The recordings are made in the first instance from sound waves picked up by a pair of suitably spaced microphones. When these recordings are "played back" simultaneously through similarly spaced loudspeakers, the reproduction has a marked "depth" or dimensional quality not obtainable with the more conventional reproduction from a single recording. In fact, the listener is given the distinct impression of being present at an original performance rather than merely hearing a reproduction; an effect that is particularly appealing in the reproduction of recorded music.

While binaural sound reproduction has this recognized superiority over its unidimensional counterpart, one of the main obstacles to widspread acceptance and use of the binaural method has been the relative complexity of binaural reproduction apparatus. The conventional approach has been to have a completely separate signal reproduction channel for each of the recordings being played, which obviously puts the binaural system at a considerable disadvantage from the standpoint of size, cost and weight. Accordingly, it is a general object of the present invention to provide a binaural sound reproduction system in which similar parts in separate signal channels are consolidated and arranged to serve in dual capacities, thereby reducing duplication of parts with attendant savings in system size, weight and cost.

As is well known, the output transformer that supplies driving power to the loudspeaker or other transducer in a sound reproduction system ordinarily is one of the heaviest and most expensive components, due primarily to the relatively bulky, heavy transformer core required. In accordance with one feature of the present invention, a lighter, more compact and less expensive binaural sound reproduction system is made possible by utilizing a common core for the output transformers in two separate signal channels. In accordance with a further feature of the invention, additional consolidation of parts is effected by winding the system power supply choke coil on the same core with the two output transformers.

A more complete understanding of the invention can be had by reference to the following description of illustrative embodiments thereof, when considered in connection with the accompanying drawing, wherein

Figure 1 is a schematic diagram illustrating electrical signal amplifiers with push-pull output in a binaural sound reproduction system embodying the present invention, and

Figure 2 is a diagram similar to Figure 1 showing single-sided or unbalanced amplifiers in a system embodying the invention.

As was previously stated, an important feature of the present invention is in the use of a single core for two output transformers in a binaural sound system. Consider, for example, the "double window" transformer core **10** shown in Figure 1. Core structures of this type are well known per se, and readily available, customarily comprising E and I shaped laminations of iron or the like that are stacked and interleaved to form the structure shown.

In accordance with the invention, on one end leg **12** of the core **10** there is placed a primary winding **14** and a secondary winding **16** forming a first transformer, while on the opposite end leg **18** there is placed a similar pair of windings **20** and **22** forming a second transformer.

The core **10** provides two similar pairs of magnetic circuits for the magnetic fields that will be produced by current flow through the primary windings **14** and **20**. Considering the winding **14**, for example, one magnetic circuit includes the end leg **12**, the adjacent portions **24***a* and **25***a* of the side legs, and the center leg **28**. A second magnetic circuit for the same winding **14** includes the end leg **12**, the side legs **24***a* and **24***b*, and **26***a* and **26***b*, and the remote end leg **18**. A similar pair of magnetic circuits, encompassing the same or corresponding components of the core **10**, can be traced for the fields of the other primary winding **20**, beginning in each instance with the end leg **18**.

With the foregoing magnetic circuits in mind, it can be seen that magnetic fields produced by suitably phased alternating current flow through the two primaries **14** and **20** will oppose each other in the end legs **12** and **18** of the core **10**. However, under the same circumstances, these fields will be additive in the center leg **28**.

If these fields are produced by currents of substantially equal intensity, flowing through similar windings, then the portion of each field that traverses the opposite end leg of the core will be substantially cancelled out by the stronger opposing field established by the winding on that particular leg. In other words, the resultant field in each end leg will be substantially entirely representative of the current flowing through the winding on that particular end leg. Accordingly, it is entirely feasible to have the output transformers for independent channels **30** and **32** of a binaural sound system wound on the same core structure **10**.

In practice, it is deemed preferable to arrange the circuits of the system to guard against "cross-talk," or interference due to channel-to-channel signal transfer that may take place through the core **10** due to imperfect circuit balancing or similar unpredictable factors. Such an arrangement may comprise a negative feedback loop for suppressing in a given channel any interfering signals introduced from an adjacent channel through the medium of the common transformer core. Such negative feedback connections for interference suppression are included in the circuits of Figure 1, which will now be described.

For simplicity, only one of the channels **30** is shown in detail, it being understood that the two channels **30** and **32** ordinarily will correspond throughout.

The channel **30** includes input connections **34** to conduct signals from a phonograph pickup or the like (not shown) to a first amplifier stage **38**. From the anode circuit of the amplifier **38**, a coupling capacitor **40** is connected to carry the amplified input signal to a phase splitter stage **42**. The phase splitter **42** will supply opposite phase signals through coupling capacitors **46** and **48** to the two sections of a push-pull amplifier **44**.

The circuits of the amplifier and phase splitter stages **38** and **42** include resistors **50** through which anode voltage is applied from a source designated B+, and a cathode load resistor **52** for the phase splitter. Also included in the phase splitter circuit is a volume control comprising a potentiometer **56** which is connected across the B+ supply in series with a voltage divider resistor **58**. The potentiometer arm **56***a* is connected to the grid circuit of

the phase splitter through an isolating resistor 60 to control the bias voltage on the phase splitter stage. A resistor 62 in the cathode circuit of the input amplifier 38 provides an impedance across which to apply a negative feedback voltage to channel input stage 18 as explained shortly.

In the output circuit of the final amplifier 44, the anode loads comprise the two sections formed by center tapping the transformer primary winding 14, with the center tap connection 14a being connected to the B+ voltage supply. The transformer secondary winding 16 is connected to the voice coil 64 of a loudspeaker-type transducer 66. The circuit of the amplifier 44 is completed by a cathode biasing network 68 and grid return resistors 54.

The feedback arrangement for suppressing cross-talk comprises a connection 69 from the transformer secondary winding 16 to the cathode circuit of the input amplifier stage 38. This connection will introduce into the cathode circuit a small signal that will be reproduced in the output circuit of the push-pull amplifier 44 as a signal of proper phase to suppress cross-talk.

It might be noted that even if some small amount of cross-talk is not completely eliminated, it will ordinarily be indistinguishable in the loudspeaker outputs. The signals reproduced in the loudspeakers will be substantially identical to begin with, so that a slight amount of cross-talk will be most difficult to detect and will not materially affect the desired "dimensional" quality of the reproduced signals.

Depending on the power output of the final amplifier stage 44 in the Figure 1 system, it is possible that the additive magnetic fields produced in the center leg 28 of the core 10 by the transformer primary currents may saturate the magnetic circuits that include this center leg, with resultant signal distortion. In any case where this possibility exists, the core structure can be altered slightly to avoid the difficulty by introducing a small air gap in that portion of the magnetic circuit wherein the magnetic fields are additive. Such an arrangement is shown in Figure 2, wherein there is shown the applicability of the features of the invention to amplifiers of the single-sided output type. Also illustrated in Figure 2 is a further feature of the invention; the utilization of the transformer core as a core for a power supply choke.

Referring to Figure 2, there is shown a combined transformer-and-choke core 70 having end legs 72 and 74, a center leg 76, and side legs 78 and 80. In this case, the center leg 76 contacts only one side leg 78, and while extending nearly entirely across the central open area of the core, terminates just short of the other side leg 80. This leaves a slight air gap 82 between the side leg 80 and the center leg 76, to increase the reluctance of the magnetic circuits that traverse the center leg 76.

As in the Figure 1 system, a pair of transformer primary windings 84 and 86 are wound on the end legs 72 and 74 together with their associated secondary windings 88 and 90. In addition, however, there is wound on the center leg 76 a coil 92 which serves as the filtering inductor or choke coil in a power supply filter circuit described hereinafter.

It will be understood that the core 70 in Figure 2 will provide similar pairs of magnetic circuits for the transformers 84, 88 and 86, 90, corresponding to the magnetic circuits previously described with respect to the core 10 in the Figure 1 system. One such circuit for each of the transformers will include the center leg 76 of the core 70 in Figure 2, and, as in the Figure 1 system, it is contemplated that additive magnetic fields will be established in this center leg. However, the reluctance increase provided by the gap 82 in the Figure 2 structure will keep down the flux density in the center leg 76 and thereby avoid saturating the important magnetic circuits that traverse this center leg. Additional protection against saturation will be provided by the field resulting from current flow through the choke coil 92, as will now be described in connection with a description of the amplifier and power supply circuits in Figure 2.

As before, only one channel 94 is shown in detail in Figure 2, and the description will be limited to this single channel, it being understood that the two channels 94 and 96 included within the broken line blocks ordinarily will be identical throughout.

In channel 94, a pair of input leads 98 are provided to conduct signals from a phonograph pickup or the like (not shown) to a first amplifier stage 100. A coupling capacitor 102 connects the anode circuit of the first amplifier 100 to the grid circuit of an output amplifier stage 104. The amplifier stages 100, 104 include the usual grid return resistors 106, as well as a cathode resistor for the input stage 100 across which to apply negative feedback voltage and a cathode biasing network 110 for the output stage 104.

Anode voltage is supplied for all stages in both channels of the Figure 2 system by a power supply circuit 114 that is shown in detail in order to illustrate a typical connection for the choke coil 92. The power supply circuit 114 comprises a transformer 116 having a primary winding 118, adapted to be connected to the usual alternating voltage supply source (not shown), and a secondary winding 120 connected for full wave rectification to a duodiode rectifier 120. The output circuit of the power supply 114 includes a filter network comprising a resistor 124 in series with the choke 92, in combination with a shunt capacitor 126.

From the choke 92, B+ voltage is applied to the anode circuits of the amplifier stages 100 and 104 through the load resistors 112 and through the transformer primary windings 84, 88 respectively.

As in the circuit of Figure 1, a feedback connection 126 is provided in Figure 2 from the transformer secondary winding 86 to the cathode circuit of the first amplifier stage 100 to suppress interfering signals that may be introduced from the other channel 94 through the medium of the common transformer core 70.

In the Figure 2 system, it is seen that the unidirectional current flow through the choke coil 92 can readily be arranged to set up a magnetic field that will oppose the fields in the center leg 76 established by similar current flow through the transformer primaries 84 and 88. This will help to avoid saturation of the center leg, as previously stated.

In addition to the parts consolidation and anti-saturation features of the choke coil arrangement shown in Figure 2, a further advantage of this arrangement is in the fact that the choke coil 92 will serve as a "hum-bucking" element.

Residual "ripple" in the power supply output sometimes is reproduced as "power hum" in the loudspeakers 66. However, with the choke coil 92 wound on the transformer core center leg 76, any such ripple will set up a field in the core 70 in a direction such as to oppose and cancel out the hum-producing fields that might otherwise exist, and thereby will eliminate any such difficulty.

It will, of course, be understood that the choke coil arrangement shown in Figure 2 can as well be used in a system such as is shown in Figure 1. Similarly, the core structures 10 and 70 of Figures 1 and 2 will be understood to be interchangeable in the circuits shown in the two figures.

What is claimed is:

1. In a binaural sound reproducing system for converting into sound waves substantially identical electrical signals derived from sound recordings, the combination of a pair of electrical signal channels each comprising means for amplifying said signals and each having an output circuit, a transformer circuit in each said channel having a primary winding and a secondary winding, said primary windings being connected in said output circuits, a transformer core comprising a structure of magnetic material having end legs, side legs connecting said end legs and a center leg extending between said side legs, the wind-

ings of said transformers being wound on separate ones of said end legs, and means connected in said channels for suppressing in each said channel interfering signals introduced therein from the other of said channels through the medium of said core.

2. In a binaural sound reproducing system, two electrical signal channels each comprising (1) signal amplifying means including an output circuit, (2) a transformer circuit having a primary winding connected in said output circuit and having a secondary winding, and (3) a transducer for converting electrical signals to sound waves and connected to said secondary winding to receive electrical signals therefrom, and a unitary core structure of magnetic material on which said windings are wound, said structure including members forming a first magnetic circuit common to both said primary windings and in which magnetic fields due to current flow through said primary windings oppose each other, and said structure also including a further member forming with said first named members second and third magnetic circuits having a common portion traversing said further member and independent portions traversing said first-named members.

3. In a binaural sound reproducing system for converting into sound waves substantially identical electrical signals derived from sound recordings, the combination of a pair of electrical signal channels each comprising means for amplifying said signals and each having an output circuit, a transformer circuit in each said channel having a primary winding and a secondary winding, said primary windings being connected in said output circuits, a unitary core structure of magnetic material on which said windings are wound, said structure including members forming a first magnetic circuit common to both said primary windings and in which opposing fields are generated by current flow through said primary windings, said structure also including a further member forming with said first named members second and third magnetic circuits having a common portion traversing said further member and independent portions traversing separate ones of said first-named members, and means connected in said channels for suppressing in each said channel interfering signals introduced therein from the other of said channels through the medium of said core.

4. A system as defined in claim 3 wherein said further member comprises an elongated element extending between separated ones of said first named members and is joined only to one of said separated members whereby said second and third magnetic circuits are interrupted by an air gap between the other of said separated members and the free end of said further member.

5. In a binaural sound reproducing system, two electrical signal channels each comprising (1) signal amplifying means having input and output circuits, (2) a transformer circuit having a primary winding connected in said output circuit and having a secondary winding, and (3) a transducer for converting electrical signals to sound waves and connected to said secondary winding to receive electrical signals therefrom, and a unitary core structure on which said windings are placed, said core comprising magnetic material forming magnetic circuits having independent portions and having a common portion, the primary windings of said transformers being wound on separate ones of said independent portions of said core structure in such directions as to generate aiding magnetic fields in said common circuit portion and opposing fields in said independent circuit portions upon energization of said primary windings, and means associated with each said channel for substantially suppressing signals coupled thereinto from the other channel through said transformer core.

6. A system as defined in claim 5 wherein said last-named means comprises a connection from each said transformer secondary winding to the input circuit of the associated amplifying means.

7. In a binaural sound reproducing system for converting into sound waves substantially identical electrical signals derived from sound recordings, the combination of a pair of electrical signal channels each comprising means for amplifying said signals and each having an output circuit, a transformer circuit in each said channel having a primary winding and a secondary winding, said primary windings being connected in said output circuits, a transformer core comprising a structure of magnetic material having end legs, side legs connecting said end legs and a center leg extending between said side legs, the windings of said transformers being wound on separate ones of said end legs, means connected in said channels for suppressing in each said channel interfering signals introduced therein from the other of said channels through the medium of said core, a power supply circuit for converting alternating current to direct current for energizing said amplifying means, and a filter network in said power supply circuit including a choke coil, said output circuits being connected to said power supply circuit to draw unidirectional current therefrom through said transformer primary windings, and said choke coil being so wound on said transformer core center leg that opposing magnetic fields are set up in said core structure by current flow through said choke coil and through said primary windings.

8. In a binaural sound reproduction system for converting into sound waves substantially identical electrical signals derived from sound recordings, two electrical signal channels each comprising (1) signal amplifying means including an output circuit, (2) a transformer circuit having a primary winding connected in said output circuit and having a secondary winding, and (3) a transducer for converting electrical signals to sound waves and connected to said secondary winding to receive amplified electrical signals therefrom, a unitary core structure of magnetic material on which said windings are wound, said structure including members forming a first magnetic circuit common to both said primary windings and in which magnetic fields established by current flow through said primary windings oppose each other, said structure also including a further member forming with said first named members second and third magnetic circuits having a common portion traversing said further member and independent portions traversing said first named members, a power supply circuit for converting alternating current to unidirectional current for energizing said amplifying means, and a filter network in said power supply circuit including a choke coil, said choke coil being wound on said further core member.

9. In a binaural sound reproducing system for converting into sound waves substantially identical electrical signals derived from sound recordings, the combination of a pair of electrical signal channels each comprising an electrical amplifier and each having an input circuit and an output circuit, a transformer circuit in each said channel having a primary winding and a secondary winding, said primary windings being connected in said output circuits, a transformer core comprising a structure of magnetic material having end legs, side legs connecting said end legs, and a center leg extending between said side legs but contacting only one of said side legs and thereby leaving an air gap between said center leg and the other of said side legs, the windings of said transformer circuits being wound on separate ones of said end legs, a connection from each said transformer secondary winding to the input circuit of the associated amplifier to suppress in each said channel interfering signals introduced therein from the other of said channels through the medium of said core, a power supply circuit for converting alternating current to unidirectional current for energizing said amplifiers, and a filter network in said power supply circuit including a choke coil, said output circuits being connected to said power supply circuit to draw unidirectional current therefrom through said transformer primary windings, and said choke coil being so

wound on said transformer core center leg that opposing magnetic fields are set up in said core structure by current flow through said choke coil and through said primary windings.

10. In a binaural sound reproducing system, two electrical signal channels each comprising (1) signal amplifying means having input and output circuits, (2) a transformer circuit having a primary winding connected in said output circuit and having a secondary winding, and (3) a transducer for converting electrical signals to sound waves and connected to said secondary winding, and a unitary core structure on which said windings are placed, said core comprising magnetic material forming magnetic

circuits having independent portions and having a common portion, the windings of said transformer circuit being wound on separate ones of said independent portions of said core structure in such directions as to generate aiding magnetic fields in said common circuit portion and opposing fields in said independent circuit portions upon energization of said primary windings.

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