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TRANSFORMERS

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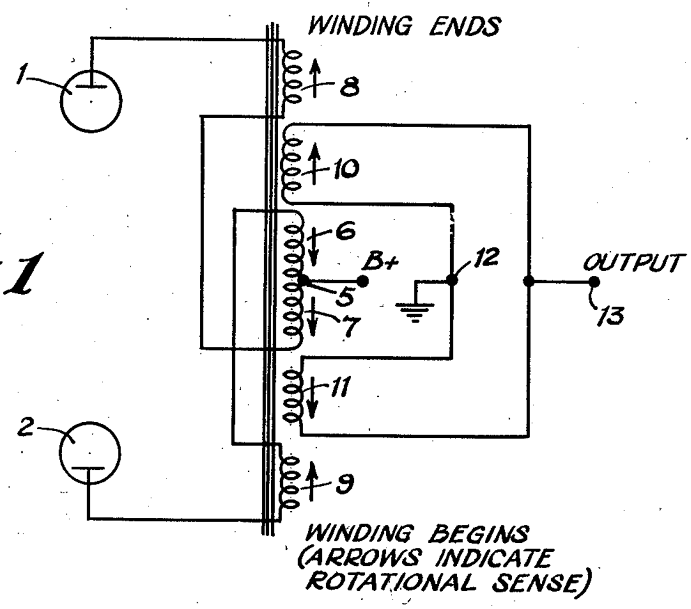

Fig. 1

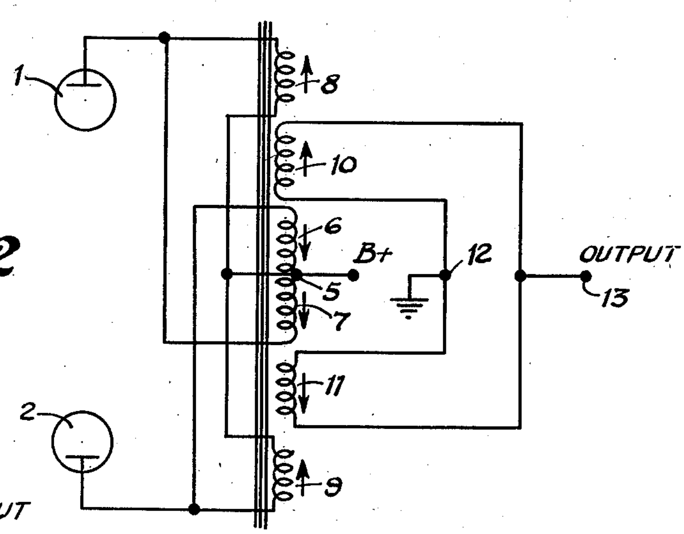

Fig. 2

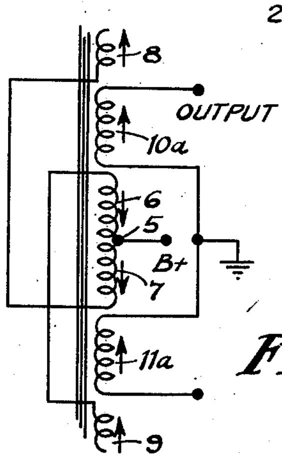

Fig. 3

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TRANSFORMERS

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The present invention relates generally to high fidelity wide band audio push-pull output transformers, which may be utilized as output transformers of any types of push-pull amplifier, and which are capable of handling large amounts of audio power with substantially low distortion, within the band at least 7–70,000 cps., and which permit utilization of as high as 30 db of negative feed-back in amplifiers, the transformers being included in the feed-back loops.

It is well understood by those skilled in the art, that high quality transformers require large amounts of copper and of iron, in order to attain desirable incremental inductance of the transformer primary windings, and thereby desired low frequency response. These requirements are not compatible with those relating to adequate high frequency response, i. e. low leakage reactance and low distributed capacitance. In addition, high fidelity transformers should desirably be capable of inclusion in negative feed-back loops having 20–30 db of negative feed-back. The requirement that high fidelity transformers be capable of operation within 20–30 db feed-back loops implies that the relative phase of signals in primary and secondary windings is accurately controlled. Undesired phase shifts occur primarily because of capacitive transfer of signals between the windings, but also because of leakage reactance. The latter is reduced by interleaving techniques, which, however, increase primary capacitance. The two factors must usually be compromised. Capacitive current transfers may be avoided by electrostatic shielding of secondary windings, but the use of shields increase capacities to ground, and limits high frequency response.

In accordance with the present invention the primary windings of audio transformers are sectionalized, and the secondary windings employed as shields between primary halves. Three superposed and co-axial primary coils are employed, the central one of which may be a center-tapped coil, the center tap being connectable to B+. The turns of this coil all proceed identically, in sense of rotation, and the coil may be considered to consist of two sections, each of which is in series with a different tube of a push-pull amplifier.

The remaining two primary coils, one of which is physically over and the other under the central coil, are wound in opposite sense to the central coil, and two secondary coils are interposed, respectively, between the central coil and the remaining two primary coils. The coil arrangement is therefore p–s–p–s–p. One of the secondary coils is wound in the same sense as the central primary coil, and the other in the opposite sense. The secondary coils are connected in parallel, or in series. If in series, they must be wound in the same sense, to obtain complete symmetry. The primary coils may be interconnected in either of two ways. In the first the outer primary coil (taken in the physical sense) is connected in series with that part of the mid-center coil which precedes the center tap, i. e. the inner half. The inner primary coil is connected in

series with that part of the center coil which follows the center tap, i. e. the outer half.

In the parallel connection, the outer coil is connected in parallel with the inner half of the center coil, and the inner coil with the outer half of the center coil. Obviously, the number of turns in the inner and outer primary sections must equal the number of turns in half the center section, for parallel connection, but not necessarily for series connection.

The transformer of the present invention accepts an unbalance in D. C. resistance and capacitance in order to provide effective interleaving of the push-pull halves, and reduced interwinding capacitance. The interleaving decreases leakage reactance between the halves, thus increasing power handling capabitities at high frequencies. The interleaving, as carried out in the present invention, does not increase interprimary capacitance. The reason for this important consequence of the invention is that push-pull halves of the primary winding are contiguous only adjacent to the center tap, which is a point of zero A. C. potential. Otherwise, the primary coils are separated by low potential secondary windings. Low capacitance across the total primary, and minimum capacitive coupling between primary halves, are essential to effect push-pull cancellation of even order harmonics, and to avoid resonances. Avoidance of the latter is essential to avoid poor transient response, and the introduction of phase shifts, which are not permissible in circuits employing large feed-back.

The secondary windings are completely balanced with respect to the several primary coils, so that capacitive transfer from primary to secondary windings is balanced out, and no longitudinal transmission occurs. True push-pull operation over a wide frequency spectrum, lack of signal on phase reversal, and high permissible feed-back, are all thereby attained.

In one design in accordance with the invention, a 2" stack of conventional scrapless lamination was employed. It was found that the transformer was capable of handling 50 watts of power, at 20 cps. and 20 kc., with negligible distortion, and that a frequency response of ±1 db from 7 cps. to 70 kc. was attained, permissible feed-back being as high as 30 db.

It is, accordingly, a broad object of the present invention to provide a novel high fidelity push-pull audio transformer.

It is another object of the present invention to provide a push-pull audio transformer having interleaved primary windings, in which secondary windings serve as capacitive shields for the primary winding sections.

Another object of the invention resides in the provision of a push-pull audio transformer having split primary halves, the two sections forming each primary half being so physically positioned as to apply to secondary sections of the transformer capacitively transferred currents of opposite phase and equal amplitude.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following details description of one specific embodiment thereof, especially when taken in conjunction with the accompany drawings, wherein:

Figures 1 and 2 are schematic circuit diagrams of alternative arrangements, in accordance with the invention; and

Figure 3 illustrates a series connection of the secondary winding sections of Figures 1 and 2, inclusive.

Referring now more particularly to the accompanying drawings, the reference numeral 1 denotes a first vacuum amplifier tube, and the reference numeral 2 a second vacuum amplifier tube, of a push-pull high fidelity audio amplifier, operating class A, AB, or B as desired. Any amplifier tube type may be employed.

An audio output transformer is provided for the amplifier, which possesses adequate copper and iron for satisfactory low frequency response in high fidelity amplifiers, and in which the primary winding 3 is of interleaved construction, to minimize leakage reactance. The primary winding consists of a central coil or section 4, wound all in one sense of rotation in superposed layers, and having at least a center tap 5, so that coil or section 4 consists physically of an exterior sub-section 6, and an interior sub-section 7, the division line being the center tap 5.

A further outer primary section 8 and an inner primary section 9, are provided, wound as separate layers respectively externally and internally of central section 4. The sections 8 and 9 are wound in opposite sense to the section 4, and sections 6 and 9 being connected in series with the anode of tube 2, and sections 7 and 8 in series with the anode of tube 1. Tracing through the sense of sections 7, 8, and 6, 9 in terms of current flow, and winding sense, starting at tap 5, it will be clear that sections 6 and 9 inductively aid each other, and that sections 7, 8 inductively aid each other, but are in opposite phase to sections 6, 9. Assuming equal numbers of turns in sections 6, 7, 8, 9, adjacent layers of sections 6, 8 and of sections 7, 9 are of opposite phase and equal potential.

A secondary section 10 is interposed between primary sections 6 and 8, and a further secondary section 11, between primary sections 7 and 9. The secondary sections 10, 11 are connected in parallel, as illustrated and in relatively reversed winding sense, but could be connected in series, if desired.

The secondary sections 10, 11 are low voltage windings, having a ground at 12. It follows that secondary sections 10, 11 are electrostatic shields, respectively, between primary sections 6, 8 and 7, 9, respectively. The shields reduce or minimize capacitance coupling between adjacent primary sections, and the location of the secondary sections intermediate primary winding layers of equal potential and opposite phase eliminates capacitive current transfer to the secondary windings.

The secondaries may be wound, by virtue of the recited arrangement, more symmetrically with respect to the primary sections than would otherwise be the situation, i. e. the grounded ends of the secondary sections are both immediately adjacent the ends of center section 4. Capacitive transfer to and from the secondary sections is thus minimized.

The entire system is unbalanced for D. C. resistance and capacitance, because the several windings are superposed, and therefore are of different diameters and wire lengths. This is accepted deliberately, in order to accomplish effective interleaving of the push-pull halves, to decrease leakage reactance between the halves, which increases power handling capabilities at high frequencies in all modes of operation, including class B. The physical relation of the windings permits the interleaving without an increase in interprimary capacitance, because the push-pull halves are contiguous only at the center tap, where zero A. C. potential exists. The primary sections are separated by insertion of the low potential secondary sections therebetween, in balanced relation. There is thus a low capacitance across the entire primary winding, and minimum capacitive coupling between primary halves. Such capacitive coupling must be avoided for true balanced operation, at all frequencies. Otherwise, desired cancellation of even order harmonics is not accomplished. Further, resonances between push-pull halves are avoided, which would otherwise cause poor transient response and limit permissible negative feed-back, because of drastic phase shifts which occur at and adjacent to resonant frequencies.

Because of the balanced relation of secondary sections with respect to primary sections, and of the latter with respect to each other, capacitive transfer from primary

to secondary is balanced, i. e. there is no unbalanced signal transfer or longitudinal transmission. Thus, there is no signal component with phase reversal of the amplifier, and permissible feed-back around the transformer is extended, and true balanced or push-pull amplification maintained over an extremely wide frequency spectrum, with minimum phase shift, accurate impedance matching and low distortion.

Referring now to Figure 2 of the accompanying drawings, there is illustrated a variant of the system of Figure 1 in which primary section 6 is connected in parallel with primary section 9, and primary section 7 in parallel with primary section 8, the circuits of Figures 1 and 2 being otherwise identical. In the system of Figure 2 the number of turns in parallel connected windings must be equal, to assure equal voltage, and therefore no circulating primary current. In the system of Figure 1 this is not necessary.

In Figure 3 of the drawings, is illustrated the series connection of secondary sections, which may be employed in either of the illustrated embodiments, sections 10*a*, 11*a* being wound in identical sense of rotation, with junction point grounded, for symmetry. In the event sections 10*a* and 11*a* are wound in opposite senses, they may be connected start to start the joint starts being grounded. This arrangement is not symmetrical.

Whether an asymmetrical secondary arrangement can be used depends on the impedance of the windings. If the impedance is only a few ohms, the entire secondary is, as seen from the primary, at ground potential. As the secondary impedance is increased, it becomes more important to use either relatively reversed paralleled windings, or relatively unreversed series windings with center point grounded in order to cancel capacitive current transfer from the primaries.

While I have described and illustrated one specific embodiment of the present invention, it will become apparent that variations of the specific details of construction may be resorted to without departing from the true spirit and scope of the invention as defined in the appended claims.

What I claim is:

1. A high fidelity audio transformer, having a first central primary section, said first central primary section having a first winding sense throughout and at least a center tap to establish an upper and lower half of said first primary section, a second primary section, a third primary section, said second primary section wound exteriorly of said first primary section and said third primary section wound interiorly of said first primary section, the winding senses of said second and third primary sections being identical, and opposite to the winding sense of said first primary section, means connecting said upper half of said first primary section with said third primary section, means connecting said lower half of said first primary section with said second primary section, said windings all on a common core.

2. The combination in accordance with claim 1 wherein is further provided a first and a second secondary section on said common core, said first secondary section interposed between the upper half of said first primary section and said second primary section, said second secondary section interposed between said lower half of said first primary section and said third primary section, and means for connecting said first and second secondary sections to a common load.

3. The combination in accordance with claim 2 wherein said secondary sections are connected in parallel to said common load.

4. The combination in accordance with claim 2 wherein said secondary sections are connected in series to said common load.

5. A high fidelity audio output transformer for connection in push-pull relation with a pair of push-pull connected electrodes of a push-pull vacuum tube pair,

comprising, a first primary section, a second primary section, a third primary section, a fourth primary section, a first secondary section, a second secondary section, said first and second primary sections having a common high positive voltage tap and being wound in identical first sense in superposition, said third and fourth primary sections wound in sense opposite to said first sense and located respectively exteriorly and interiorly of said first and second sections, means connecting said first and third primary sections with one of said electrodes in inductively additive sense, means connecting said second and fourth primary sections with the other of said electrodes in inductively additive sense, and means for interposing said first and second secondary sections, respectively, between said first and third sections, and between said second and fourth sections respectively.

6. The combination in accordance with claim 5 wherein said secondary sections are connected in parallel, and are wound in respectively opposite senses.

7. The combination in accordance with claim 5 wherein said first and third primary sections are connected in parallel and wherein said second and fourth primary sections are connected in parallel.

8. The combination in accordance with claim 5 wherein said first and third primary sections are connected in series, and wherein said second and fourth primary sections are connected in series.

9. A winding arrangement for a push-pull output transformer, comprising a pair of primary winding sections, said winding sections wound in respectively opposite senses, means for connecting said winding sections between a B+ voltage terminal and an anode terminal in inductively additive sense, and at least one further

primary winding section intermediate said first mentioned primary winding sections.

10. A primary winding for an audio transformer, comprising two oppositely phased winding sections of identical winding sense arranged in immediate juxtaposition, two further oppositely phased winding sections of identical winding sense, opposite to said first winding sense, said two further winding sections separated at least by said first mentioned winding sections.

11. A push-pull transformer, comprising two first oppositely phased primary winding sections, a first secondary winding section directly intermediate said two oppositely phased primary winding sections, two further oppositely phased primary winding sections, a further secondary winding section directly intermediate said further two oppositely phased primary winding sections, said secondary winding sections being wound and interconnected in such senses as to provide additive outputs.

12. The combination in accordance with claim 11 wherein inductively aiding pairs of said primary sections, each pair comprising one section from each of said two first and further primary sections, are each connected with an anode terminal.

13. The combination in accordance with claim 12 wherein said pairs are series connected pairs.

14. The combination in accordance with claim 12 wherein said pairs are parallel connected pairs.

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