May 7, 1957 H. I. KEROES 2,791,646

ELECTRICAL SYSTEM FOR ULTRALINEAR AMPLIFIER

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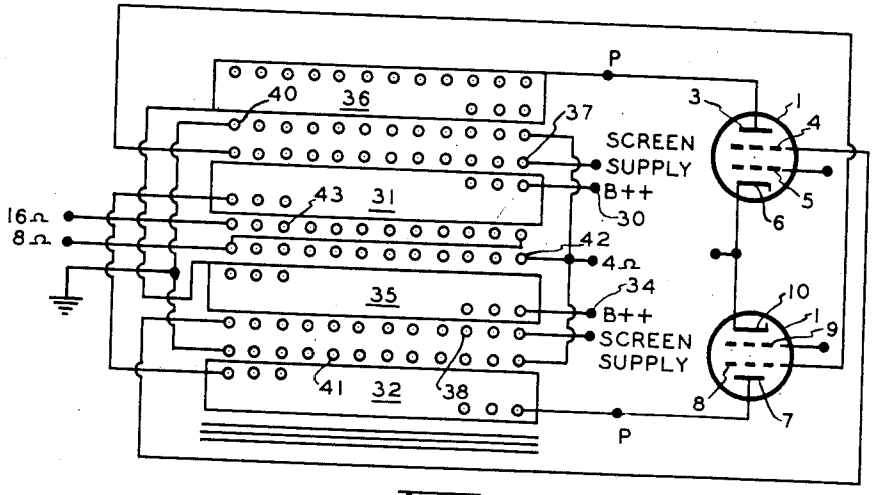


FIG. 1

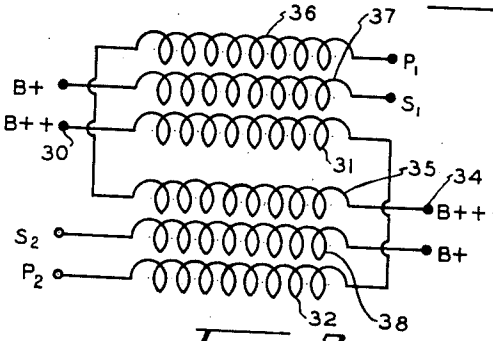


FIG. 2

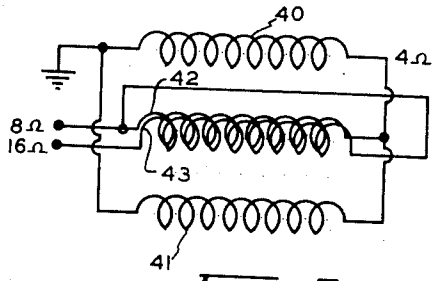


FIG. 3

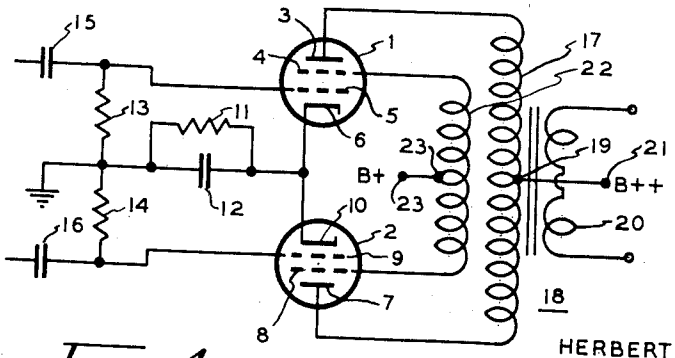


FIG. 4

INVENTOR
HERBERT I. KEROES

BY Hyman Kurtz

ATTORNEY

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ELECTRICAL SYSTEM FOR ULTRALINEAR AMPLIFIER

Herbert I. Keroes, Philadelphia, Pa.

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6 Claims. (Cl. 179—171)

The present invention relates generally to audio amplifiers, and more particularly to high fidelity audio amplifiers operating at high efficiency, and to transformers employed therein.

The present invention is an improvement of that disclosed and claimed in United States Patent No. 2,710,312, issued to Keroes et al. That patent discloses an audio amplifier of the high fidelity type, which operates class B or class AB, i. e. in push-pull, and with a grid bias selected to assure that two push-pull connected tubes shall conduct in alternation. Applicants, in the above identified patent, disclose a system in which the amplifier tubes employed have screen grids, which are connected to relatively critical points of an output transformer, whereby to optimize simultaneously a number of operating characteristics of the amplifier. This operative condition is denominated ultra-linear operation, herein. Applicants also disclose that the screen grids may be driven from a tertiary winding of an output transformer. Screen grid drive by means of a tertiary winding may be essential where the tube types employed require different D. C. voltages at the anodes and screen grids, respectively.

The schematic circuit diagram of a system of the general type above briefly described appears to be relatively simple and straightforward. The actual physical arrangement of windings, in an actual transformer, is another matter, and it is with the problem of physical arrangement and connection of the several windings of a push-pull output transformer, in which tertiary screen grid windings are employed, that the present invention is concerned.

Briefly describing the invention, a pair of electronic amplifier tubes are connected in push-pull relation, and are biased preferably for class B or class AB operation. The tubes are driven in balanced relation, and drive an output transformer having a push-pull primary winding, and a secondary winding. A tertiary winding is assembled on a common core with the primary and secondary windings, and is employed to drive the screen grids of the tubes congruently with the anodes, but in association with a lower impedance. Accordingly, the screen grids follow the A. C. excursion of the anodes, but at a reduced A. C. level. The screen grids may be supplied with D. C. voltage from a separate source than that which supplies the anodes, where the anodes and screen grids require different D. C. operating voltages.

In accordance with the present invention, the primary winding is arranged as four interleaved concentric sections, superposed. The innermost layer of the innermost section (No. 1) and the outer layer of the outermost section (No. 4) are connected, respectively, to the anodes of a pair of push-pull connected tubes. The remaining sections, i. e. No. 2 and 3, starting at the core, are connected to a source of anode voltage, the innermost layer of section No. 2 and the outermost layer of section No. 3 being so connected. Sections No. 2 and 4 are connected in series to one anode, and sections No. 3 and No. 1 to the other anode, in the recited order.

Accordingly, the primary winding is arranged as four interleaved concentric sections, two of which, in series, provide one of the primary halves, and the remaining two of which in series provide the other of the primary halves. The secondary winding is composed of three axially concentric sections, two of which are of equal number of turns. The latter two sections are connected in parallel, and interleaved, respectively, one between the two innermost primary sections and the other between the remaining two. The parallel connected sections provide a low impedance secondary winding which is symmetrically arranged with respect to the primary winding sections, and evenly distributed thereamong; and which therefore is electrically in balance with respect to the primary windings, i. e. possesses equal capacitance with respect to each half of the primary. Capacitive coupling from the secondary to each primary half is approximately the same, and since voltage on one side of the section is arranged to be of opposite phase to that on the other side, capacitive coupling is effectively balanced out.

The remaining section of the secondary winding is formed of two separate conductors, parallel wound to form a "re-entrant" series connection, where the term re-entrant means parallel wound mutually insulated conductors, each in series with the other by connecting the terminal point of one to the initial point of the other.

One of these conductors is connected in series with the low impedance secondary to provide a secondary of intermediate impedance. Both re-entrant conductors in series with the low impedance secondary provide a high impedance secondary. The secondary windings so formed each remains symmetrical with respect to the primary windings, the re-entrant conductors being located between primary sections No. 2 and No. 3.

The tertiary windings are interleaved, between the primary pairs, each tertiary winding immediately adjacent a primary layer most directly connected to the B+ terminals, and is usually a single layer, although more than one layer may be employed. This location assures minimum capacitive current to the tertiary sections, and minimum leakage reactance, since the direction of the screen winding is the same both in rotation and in starts and finishes as for the adjacent primary plate section, and since the tertiary winding is shielded from the remaining adjacent primary section by a secondary section, which is essentially at ground potential.

The primary windings are so arranged that their mutual inductance adds to the series inductance of the separate winding sections, to establish maximum inductance in each primary half for the amount of copper and iron employed in the transformer.

The physical distribution and winding relation of the tertiary windings with respect to the primary sections, which effects minimum voltage with respect to one adjacent primary section and a shielded relation to the other, implies minimum leakage reactance between windings, and minimum capacitive transfer. The fact that each tertiary winding is between two primary windings of opposite phase tends to balance out, or to minimize, capacitive current flow between the primary and tertiary windings. Since the secondary windings are in balanced relation to the primary sections, capacitively, and since leakage reactance is minimized, the entire system of windings is intercoupled capacitively to a minimum extent, and the leakage reactance between each pair of windings is minimized.

It is, accordingly, an object of the present invention to provide a novel ultra-linear amplifier, in which a pair of push-pull connected screen grid amplifier tubes is provided with optimum coupling between anodes and screen grids, by means of a tertiary winding, which is

part of an output transformer having minimum inter-winding capacity and leakage reactance.

It is still another object of the present invention to provide a novel high fidelity audio transformer having tertiary windings, in which minimum capacitive coupling and minimum leakage reactance exists, between primary windings and the tertiary windings, and between secondary windings and the tertiary windings, as well as between primary and secondary windings.

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

Figure 1 is a schematic circuit diagram of an ultralinear amplifier, which illustrates the physical arrangement of the several windings of the transformer;

Figure 2 is a schematic circuit diagram of the primary and tertiary winding arrangement of a transformer in accordance with the present invention;

Figure 3 is a schematic circuit diagram of a secondary winding in accordance with the invention; and

Figure 4 is a schematic circuit diagram of a push-pull ultralinear amplifier, having no regard to winding arrangement.

Proceeding now by reference to the accompanying drawings, and particularly Figure 4 thereof, the reference numerals 1 and 2 denote, respectively, a pair of push-pull connected tetrodes. The tetrode 1 includes an anode 3, a screen grid 4, a control grid 5 and a cathode 6. The tetrode 2 includes an anode 7, a screen grid 8, a control grid 9 and a cathode 10. The cathodes 6 and 10 are connected together, and to ground via a bias resistance 11, which is shunted by a large condenser 12, which represents essentially a short circuit for all frequencies within the high fidelity audio band, i. e. 30–20,000 C. P. S.

The control grids 5 and 9 are connected to ground via grid leaks, 13, 14 respectively, and are coupled to a high fidelity audio source (not shown) via balanced coupling condensers 15, 16 respectively.

The anodes 3 and 7 are connected to opposite ends of a high impedance primary winding 17, of a transformer 18, the center point 19 of which is tapped, to provide a B+ + terminal, 21. A secondary winding 20 is coupled to the primary winding 17, and serves as an output winding. A tertiary winding 22 is also coupled to primary winding 17, and drives the screen grids 4 and 8, developing A. C. voltages which duplicate those across primary winding 17, except in respect to magnitude. The tertiary winding 22 is center tapped at 23, to enable balanced connection to a B+ terminal 23.

The D. C. voltages applied to terminals 21 and 23 are, or may be of different magnitudes, and the relation of the number of turns in the windings 17, 22 may be selected to establish ultralinear operation, in the sense of United States Patent No. 2,710,312, hereinabove referred to.

Referring now to Figure 2 of the accompanying drawings, the reference numeral 30 denotes an anode voltage terminal of a half primary transformer winding, including two sections 31 and 32, connected in series, and so wound on a common core that the inductances of the windings add, and the mutual inductance further adds, whereby maximum inductance is associated with the primary half, for a given amount of iron and copper in the transformer. The terminal 34 is a further anode voltage terminal, and is connected to winding sections 35, 36, in series. The anode terminals of the transformers are denoted P.

The screen winding 37 subsists between windings 31 and 36, and is co-extensive with and wound in the same sense as, and starts at the same point as, the winding 31, and is immediately adjacent thereto. Similarly, screen winding 38 is co-extensive with winding 35, and is wound similarly and initiates and terminates similarly, and is immediately adjacent thereto. It follows that capacitive current between windings 31, 37, is minimized, as well as capacitive currents between windings 35 and 38, because relative A. C. voltage excursions are eliminated. Moreover, leakage reactance is also minimized, because the windings are axially co-extensive and immediately adjacent. Moreover, secondary winding 37, which is adjacent to ground in potential, acts as a shield between screen winding 37 and primary winding 36, and minimizes capacitive transfer from winding 36 to tertiary winding 37. Similar considerations apply to tertiary winding 38, which is shielded from winding 32, for capacitive transfer, by secondary winding 41.

The arrangement of secondary windings is illustrated in Figure 3 of the accompanying drawings, and includes two parallel connected windings 40, 41, which together make a 4 ohm winding. Two further bifilarly related windings 42, 43 are included. The winding 42 may be connected in series with windings 40, 41 taken in parallel, to form an 8 ohm winding, or winding 43 may be connected re-entrantly with winding 42 to form a 16 ohm winding.

The secondary winding 40 is physically located intermediate primary windings 31, 36, and secondary winding 41 intermediate primary windings 32, 35. Voltage induced in the separate secondary windings by the separate pairs of primary windings, oppose each other insofar as due to capacitive coupling, and hence balance out. The physical relations of the windings, i. e. the fact that the secondary windings are co-extensive with the primary windings axially, and located intermediate primary pairs of opposite phase, reduces, respectively, capacitive coupling and leakage reactance.

It will be noted that the winding directions of winding sections 31, 32 are opposite, i. e. one starts from the right and the other from the left, and that the terminal point of winding 31 is connected to the initial point of winding 32. Correspondingly, the rotation of winding is the same, so that the magnetic fluxes produced by the separate sections are additive.

Since the screen windings 37, 38 are immediately adjacent the primary winding layers of highest D. C. potential, i. e. adjacent the supply lead, the total A. C. capacitive charging current to the screen winding is minimized, and insulation requirements are reducted. At the same time the secondary winding operates as a screen, to at least partially shield the screen windings 37, 38 from the primary sections 31, 35.

The overall arrangement of windings, considered in their physical and electrical relations, provide a high fidelity transformer having a screen driving tertiary winding, wherein the latter does not detract from ultralinear operation, by virtue of capacitive coupling therewith of other windings, or by virtue of leakage reactance.

While I have described and illustrated one specific embodiment of my invention, it will be clear that variations of the general arrangement and of the details of construction which are specifically illustrated and described 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. An ultralinear amplifier having a first electronic amplifier tube having a first anode, cathode, screen grid and control grid, a second electronic amplifier tube having a second anode, screen grid, control grid, and cathode, means for biasing said amplifier tubes for alternative conduction in succession, an output transformer for said amplifier, said output transformer having two first primary winding sections and two second primary winding sections, said first and second sections arranged in alternation and co-axially, whereby said first primary winding sections are separated by a second primary winding section, and said second primary winding sections are separated by a first primary winding sections, said first primary winding sections being wound in opposite direc-

tions, said second primary winding sections being wound in opposite directions, the sense of winding of said sections such as to maximize primary inductance and to minimize leakage reactance and capacitive coupling, and two tertiary windings respectively connected to said screen grids and coupled to said primary windings, each of said tertiary windings being physically located intermediate a first and second primary winding.

2. The combination in accordance with claim 1 wherein each of said tertiary windings is co-extensive axially with one of said primary winding sections.

3. The combination in accordance with claim 2 wherein the point of highest D. C. potential of one of said tertiary windings and the highest D. C. potential of one of said primary windings are immediately adjacent one another.

4. In combination, a push-pull amplifier having a push-pull output transformer, said push-pull output transformer having an output winding having first, second, third and fourth multi-layer winding sections, said sections arranged co-axially, means for connecting an anode voltage supply to the outermost layer of turns of said second section, means for connecting an anode to the innermost layer of said fourth section, means connecting an anode voltage supply to the innermost layer of said third section, means for connecting an anode to the outermost layer of said first section, means for connecting said third and first sections in series, said first and third sections relatively wound to provide maximum inductance, means for

connecting said second and fourth sections in series, and second and fourth sections relatively wound to provide maximum inductance.

5. The combination in accordance with claim 4, wherein is provided a tertiary winding, said tertiary winding having a first winding element and a second winding element, said first winding element comprising at least one winding layer superposed on the outer layer of said second section, and wound identically in sense and extent with said outer layer of said second section, said second element comprising at least one winding layer wound immediately under the inner layer of said third section, and wound identically in sense and extent with said inner layer of said third section.

6. The combination in accordance with claim 5 wherein is provided a secondary winding in said transformer, said secondary winding including a first, second, third and fourth secondary section, said first and second secondary sections connected in parallel, said first section located intermediate said first tertiary element and said first primary section, said second secondary section located intermediate said second tertiary element and said fourth primary section, and said third and fourth secondary sections re-entrantly connected in series with each other and with said parallel connected first and second secondary sections and located intermediate said second and third primary winding sections.

No references cited.