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W. J. SHACKELTON

TRANSFORMER CIRCUITS

Filed Aug. 21, 1922

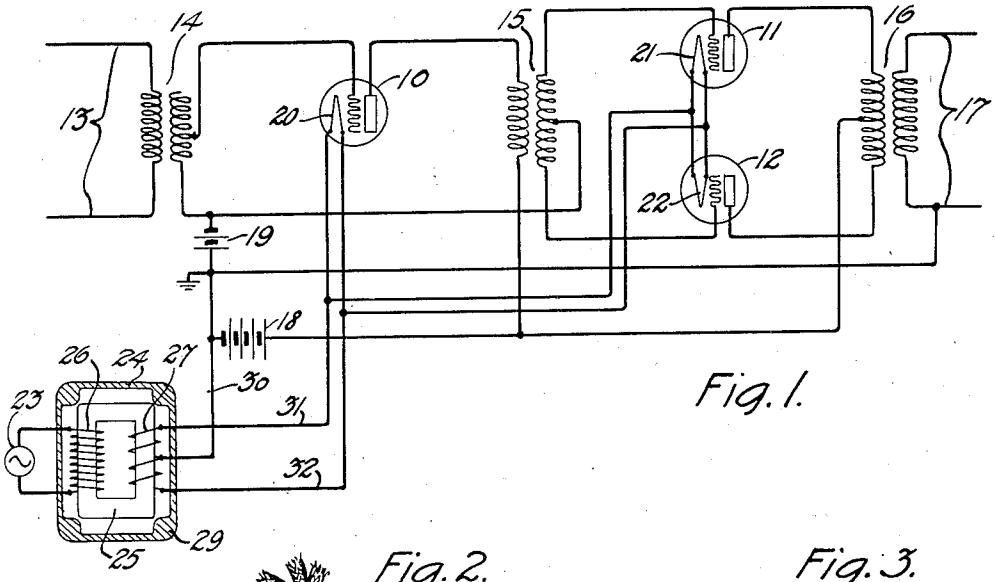


Fig. 1.

Fig. 2.

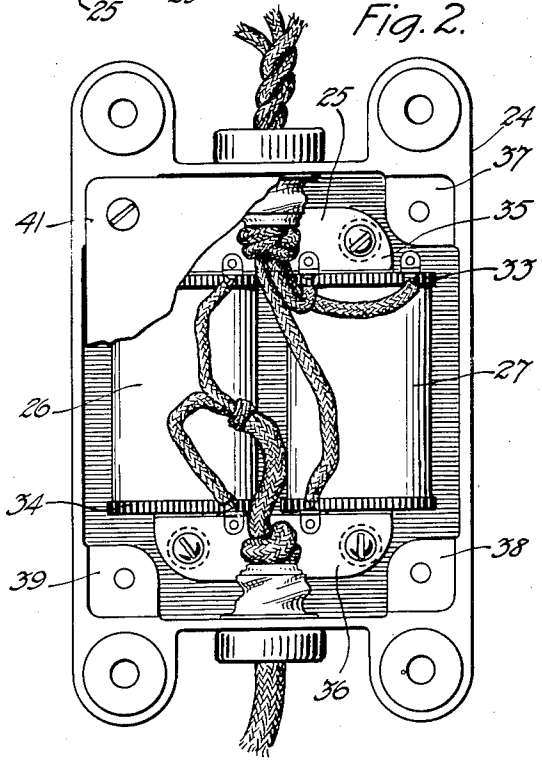
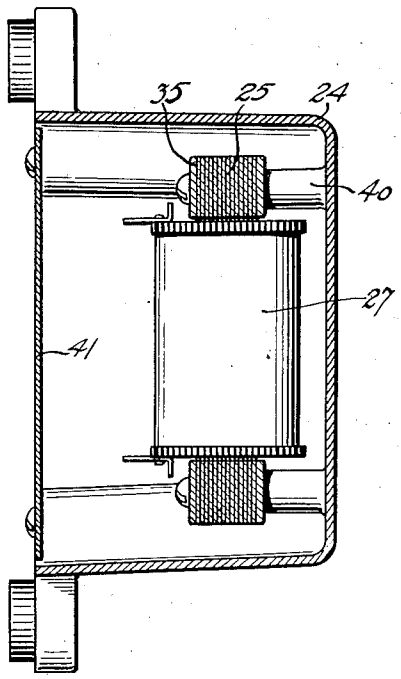


Fig. 3.



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UNITED STATES PATENT OFFICE.

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TRANSFORMER CIRCUITS.

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This invention relates to transformers and transformer circuits, particularly transformer circuits for electrical discharge devices.

An object of this invention is to provide a transformer particularly suitable for aiding in the suppression of a certain frequency or band of frequencies.

Another object is to provide a transformer of such a character that one of its windings may be short-circuited for an appreciable time without injurious heating effects resulting therefrom.

In the specific embodiment of this invention hereinafter described, these objects are accomplished by supplying a vacuum tube filament with alternating current through a transformer designed to have a high leakage reactance. This high leakage reactance may be produced, for example, by placing the primary and secondary windings on different parts of the core structure leaving other parts of the core structure bare so that a substantial portion of the flux produced by each winding finds a return path through the air or the transformer casing instead of through that part of the core surrounded by the other winding. It has been found that connecting a source of alternating current to a vacuum tube filament through such a transformer has a decided advantage in that the leakage reactance of the transformer is equivalent to inductances or retard coils in series with the primary and secondary windings, so that these equivalent inductances operate to choke out to a substantial degree the harmonics of the alternating current which otherwise would be impressed upon the vacuum tube filament so as to produce objectionable variations in the space current of the vacuum tube repeater and render the vacuum tube circuit noisy. A high leakage reactance transformer in the above described position is also of advantage in that the transformer will not be dangerous from a fire hazard standpoint in case the secondary winding should be accidentally short-circuited.

Referring to the drawings,

Fig. 1 illustrates the transformer of this invention employed in a multi-stage amplifier circuit for supplying alternating heating current to the vacuum tube repeater filaments.

Fig. 2 is a bottom view in plan of the transformer.

Fig. 3 is a side view of the transformer.

Referring particularly to Fig. 1, a multi-stage amplifier circuit is disclosed therein comprising a vacuum tube repeater 10 in the first stage, and two vacuum tube repeaters 11 and 12 connected in push-pull relation in the second stage. Each of the tubes 10, 11, and 12 is illustrated as of the three electrode type, each comprising an anode, a filamentary cathode and a grid or control electrode. The input electrodes of tube 10 are connected to the incoming line 13, 13 by an input transformer 14, while the output circuit of tube 10 is connected to the input circuits of tubes 11 and 12 by an intermediate transformer 15. Transformer 16 serves to couple the output circuits of tubes 11 and 12 with the outgoing line 17, 17. Space current for the three tubes is provided by a common source of voltage 18 connected between the cathodes and the anodes of the three tubes. Source of voltage 19 may be employed for supplying the desired static potentials between the control electrodes and the cathodes of the various tubes.

In order to supply the vacuum tube filaments 20, 21 and 22 with heating current from a source 23 of alternating current, which, for example, may be such a source as is used commercially for the 110 volt 60 cycle type of electric lighting a transformer 24 of special construction is connected between the said source and the filaments. Transformer 24 (see also Figs. 2 and 3) is shown to be of the type comprising a rectangular core 25, having a high voltage winding 26 on one side of the core, and a low voltage winding on another part of the core, whereby an appreciable portion of the rectangular core is not surrounded by turns of windings. Since the bare portions of the core 25 are so placed as to be closely adjacent portions of the metallic transformer casing 29 of magnetic material, such as iron, it follows that the transformer will have a high leakage because an appreciable portion of the flux through each winding will find a return path through the air and the transformer casing instead of through that part of the core surrounded by the other winding. This high leakage reactance effect in the transformer 24 has been found to be of

special advantage in aiding in the suppression of harmonics of the alternating current source 23, because the high leakage reactance is equivalent to inductances or retard coils connected in series with the primary and secondary windings of the transformer, so that the choking action produced by the high leakage reactance is the same as if retard coils were actually added to the circuit in series with both windings. The appreciable reduction in the harmonics of source 23 produced thereby is essential, since these harmonic frequencies, if impressed on the filament, would tend to make the amplifier circuit noisy due to the production of variations in the electron emission of the filaments and consequently in the intensity of the space current. This effect would particularly be serious in a multi-stage amplifier circuit where the impression of the harmonics on the filament of the first stage tube would produce space current variations which would be impressed on the subsequent stages of the amplifier and consequently would be amplified by the other stages. The source 23 should preferably be of substantially constant voltage output in order to maintain the cathodes at a constant temperture.

In order to obtain further aid in the suppression of the harmonics of source 23, as well as the fundamental frequency of the said source, it will generally be preferable to connect winding 27 of the transformer to the vacuum tube circuit in the following manner: The control electrodes and the anodes of the tubes should be connected by a lead 30 to the midpoint of the winding 27, while the cathode terminals are connected by leads 31 and 32 to the outside terminals of winding 27. One way in which the lead 30 may be connected to the midpoint of winding 27 to a close approximation, is by winding the two halves of winding 27 as a parallel or twisted pair.

This mid-tap connection, however, aids in the suppression of only the odd harmonics from the A. C. heating source, using the nomenclature that the fundamental is the first harmonic, the double frequency the second harmonic, etc. That is, it has been found that the connection of the grid and anode to the midpoint of the secondary winding is effective in maintaining the cathode at a constant average potential with respect to the grid and anode only for the odd harmonics and not for the even harmonics. Even if the impressed A. C. wave is symmetrical so that no even harmonics are present, it has been found that the presence of the odd harmonics in the filament even to a small extent causes the tube space current to have components indicating the modulation of the higher odd harmonics by the lower odd harmonics. For example, the 13th harmonic will be modulated by the fundamental which, for example, may be 780 cycles modulated by 60 cycles. This modulation produces two side bands of 720 and 840 cycles, which are even harmonics, the 12th and the 14th, respectively. For this reason the mid-tap connection alone is not sufficient to suppress noise even when the even harmonics are not present in the impressed voltages. In accordance with this invention, however, a coil having high leakage reactance, is used to couple the filament to the A. C. source, so that the transmission efficiency of the coil falls off rapidly with the frequency. This results in transmitting the harmonics much less efficiently than the fundamental, thereby aiding in the suppression of the odd harmonics, which tend to cause noise due to the modulation above referred to.

The amount of leakage reactance to be employed will depend, of course, upon the load and the voltage of the source. For a 110 volt 60 cycle source working into three filaments requiring a voltage of 5.4 volts across the secondary winding, a transformer having from 30% to 60% leakage reactance will in general be satisfactory, as compared with a transformer of perfect coupling having no leakage reactance. Beneficial results can be obtained with a leakage reactance as low as 10%, but in general the higher the leakage reactance, the better, providing the transformer is maintained sufficiently efficient to deliver the proper current to the load. A leakage reactance greater than 60% would, therefore, be feasible particularly if the impressed voltage is high and the load is small.

As shown in Fig. 2, the secondary winding 27 is wound on a spool 33, while the primary winding 26 is wound on a spool 34, the two spools being located on different parts of the core 25. The end portions 35 and 36 of the core are shown to be closely adjacent the corners 37, 38, 39 and the fourth corner, not shown, of the casing in order to make the transformer of high leakage reactance. The core 25 is preferably composed of laminations or strips of magnetic material stacked to the desired thickness. The core is mounted in the casing by screws which fasten the core to four posts 40, which are integral with the casing. A suitable plate 41 may be employed for closing the bottom of the casing. As illustrated, it will generally be preferable to bring the primary winding leads and the secondary winding leads out from opposite sides of the transformer casing.

The actual method employed in producing a rectangular core 25 may be varied considerably as desired. For example, each layer of the core 25 may be composed of two L shaped strips with their ends closely adjacent. Each layer, however, may be made in

any suitable way in which the L shaped pieces may or may not be employed.

It is to be understood that this invention is not limited to the specific disclosure, but may be embodied in widely different forms without departing from the spirit of this invention, as defined in the appended claims.

The invention claimed is:

1. A transformer for supplying a load circuit with substantially pure sine wave voltage from an alternating current source, said transformer having primary and secondary windings, one winding being formed in two balanced portions, said windings being so proportioned with respect to the frequency of said alternating current that the fundamental frequency is readily transmitted, and a core structure for said transformer adapted to produce a substantially symmetrical flux leakage around each portion of said one winding, providing leakage reactance sufficient to filter out from said load circuit and from across the terminals of each of said winding portions harmonics in said alternating current source.

2. A transformer particularly for supplying a three-electrode vacuum tube repeater with substantially pure sine wave voltage from an alternating current source, comprising primary and secondary windings, the secondary winding being provided with outer terminals for connection to the filament of the tube to supply heating current therefor, and with a center tap for connection to the input and output terminals of said repeater, said transformer having a substantially closed core, said primary winding and each half of said secondary winding being disposed on different portions of said core, and a magnetic shunting means cooperating with said core for producing substantially symmetrical flux leakage for both halves of said secondary winding sufficient to suppress harmonics between the outer terminals of said secondary and also between the center tap and either outer terminal of said winding.

3. A transformer according to claim 2 in which said magentic shunting means is provided by the casing of said transformer.

4. A transformer for supplying a three-wire circuit from a two-wire circuit comprising a primary and a split secondary winding. leads from the outer and center terminals of said secondary winding respectively, a core for said windings, and means providing flux leakage between said primary and secondary windings for reducing harmonics from said two-wire circuit in said three-wire circuit, said leakage being substantially symmetrical with respect to both halves of said secondary winding, whereby the center lead remains at the mid-potential of the outer leads for both the fundamental and harmonic components.

In witness whereof, I hereunto subscribe my name this 16th day of August A. D., 1922.

WILLIAM J. SHACKELTON.