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HIGH RATIO VACUUM TUBE INPUT TRANSFORMER

Original Filed Jan. 11, 1963

FIG.1.

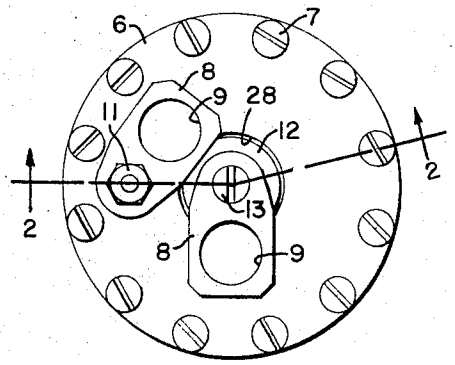


FIG.2.

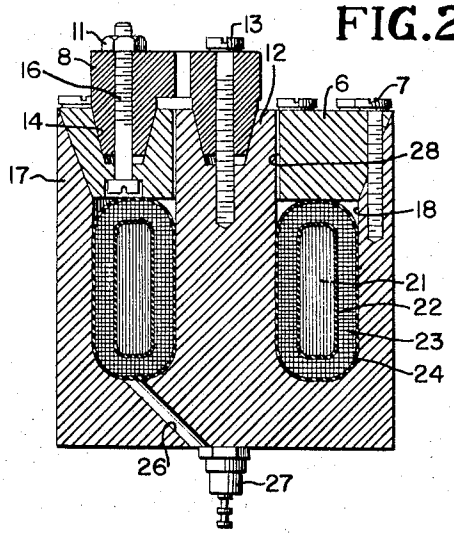
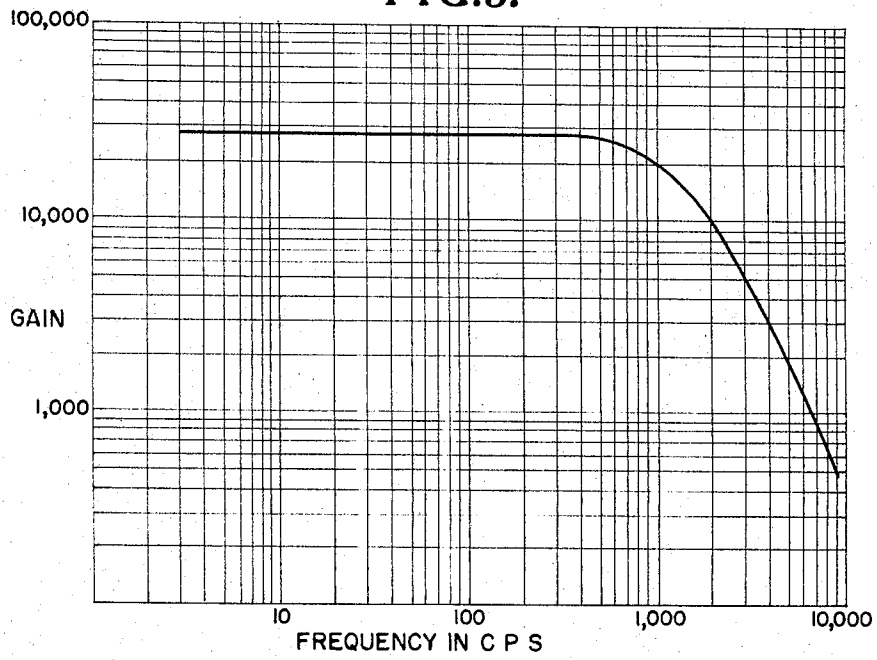


FIG.3.



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3,353,130
HIGH RATIO VACUUM TUBE INPUT TRANSFORMER

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Continuation of application Ser. No. 250,964, Jan. 11, 1963. This application Aug. 11, 1965, Ser. No. 483,001
3 Claims. (Cl. 336—82)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This is a continuation of application Ser. No. 25,964, now abandoned, filed Jan. 11, 1963.

The present invention relates to a new and improved transformer and more particularly to a high ratio voltage step-up transformer having maximum sensitivity and bandwidth in which a low frequency, low resistance detector input is raised to the point where the voltage output of the transformer exceeds the thermal noise of a vacuum tube to which is connected as an input.

Prior art transformers, although satisfactory for their intended use, have not been entirely satisfactory for stepping-up a voltage, near the magnitude of the inherent thermal noise voltage of the detector, to a point in excess of the input noise of a vacuum tube amplifier, since existing transformer designs make oscillation practically unavoidable when a very high step-up transformer is combined with a high gain amplifier due to the stray fields from the amplifier being fed back to the transformer at its resonant frequency. The normal method of eliminating this oscillation is to connect a damping resistance to the transformer, however, this is not satisfactory when the voltage from the detector is in the range near the inherent thermal noise voltage of the detector because the available signal voltage output is substantially reduced.

The present invention provides a large mass, low resistance single turn primary which additionally functions as an outer casing as well as an electromagnetic radiation shield for the secondary and the magnetic core of the transformer. Contained completely within the primary winding is the toroidal magnetic core surrounded by the high number of turns of the secondary winding thereby providing the maximum flux linkage possible by containing the secondary winding and its magnetic core completely within the field of the primary winding while at the same time being effectively shielded from stray electromagnetic radiation. The magnetic coupling and shielding provided by the transformer enables a small detected voltage, in the range of the thermal noise voltage of the detector, to be stepped-up sufficiently so that the output voltage from the secondary exceeds the inherent shot noise and flicker effect of a vacuum tube while at the same time eliminating stray electromagnetic radiation from adversely affecting the operation of the transformer.

An object of the present invention is to provide a transformer for increasing the sensitivity and bandwidth of a low resistance detector at very low frequencies by stepping-up the voltage output of the detector to a point where the thermal noise of the detector exceeds the normal input noise of a vacuum tube to which the output of the transformer is connected.

Another object is to provide a step-up transformer in which the thermal noise voltage of a low resistance detector is stepped-up to a point equal to the flicker noise of a vacuum tube at very low frequencies.

Still another object is to provide a step-up transformer

having an increased high frequency response by decreasing the shunting capacitance.

A further object is to provide a step-up transformer having a single turn primary which shields the transformer of a stray electromagnetic radiation.

Another object is to provide a high ratio voltage step-up transformer having a substantially flat frequency response over a wide frequency range without the use of a secondary load.

Other objects and features of the invention will become apparent to those skilled in the art as the disclosure is made in the following description of the preferred embodiment of the invention as illustrated in the accompanying sheet of drawing in which:

FIG. 1 is a top view of the transformer of the present invention showing the input terminals of the primary winding;

FIG. 2 is a side view of the transformer taken along lines 2—2 of FIG. 1 showing in section the primary winding, with the secondary winding and the magnetic core enclosed therein; and

FIG. 3 is a graph showing the flat response of a gain of the present transformer over a wide frequency range.

Referring to FIG. 1 which illustrates a top view of the transformer there is the cover plate 6 with the plurality of screws 7 therethrough. There are also a pair of primary winding lug connectors 8 each having an aperture 9 therein for joining the output leads of a low resistance detector (not shown) to the primary winding of the transformer. A fastening nut 11, as part of a bolt, maintains electrical contact between one lug connector 8 and the cover plate 6. The other lug connector 8 is maintained in electrical contact with the center projection 12 of the primary winding casing by means of a screw 13.

In FIG. 2 the cover plate 6 is illustrated as the frustum of a right circular cone with a concentric hole therethrough having a conical shaped hole 14 therein for receiving one of the complementary shaped lug connectors 8 maintained in tight electrical connection by the bolt 16 with the nut 11 on the end thereof. A cup-shaped or closed cylindrical member 17 formed of a conductive material, such as copper, and having a center interior projection integral therewith forms a single turn primary and also a housing for the secondary winding and magnetic core as will be described infra. The cup-shaped member 17 has a tapered side wall at the uppermost portion as viewed in the drawing conforming in shape to the side walls of the cover plate 6 to form a good electrical contact between the cover plate and cup-shaped member. A plurality of screws 7 pass through apertures in the cover plate and engage tapped holes in the cup-shaped member to maintain the electrical contact between the cover plate and the cup-shaped member. The center interior projection has a tapped hole and a second conical shaped hole concentric therewith complementary in shape to the second primary lug connector 8. The screw 13 maintains electrical connection between the lug connector and the center projection. All of the electrical conducting members such as the lug connectors 8, the cover plate 6, and the cup-shaped member are formed of electrical conductive material such as copper or aluminum.

Also illustrated in FIG. 2 is a toroidal shaped cavity 18 formed by the cover plate 6, the cup-shaped member 17 with the center projection 12. Contained within the toroidal shaped cavity 18 is a magnetic core 21 formed of a permalloy-type of magnetic allow with a maximum permeability in excess of one million and generally known by the trade name of Supermalloy. The magnetic core can be formed of Supermalloy tape and has an insulative cover-

ing 22 encasing the magnetic core. Encircling the insulative covering are many turns of fine conductive wire, in the order of 30,000 turns in the illustrative embodiment. Surrounding the secondary winding 23 is a second thin insulative covering 24. The turns of the secondary winding are each insulated from each other so that the step-up ratio of the transformer is equivalent to the number of turns on the secondary winding since the primary winding is a single turn winding. The current enters one of the primary connectors 8 and encircling the secondary winding and leaves from the second primary connector 8. A small channel or conduit 26 is formed in the cup-shaped member 17 to provide the passage for the two ends of the secondary winding (not shown) from the toroidal shaped cavity to the exterior secondary winding terminal 27. Two secondary winding terminals 27 are provided, although only one is shown since the second one is in direct alignment with the one shown and is identical in construction. An insulative space 28 is provided between the cover plate 6 and the center projection 12 so that the current of the primary winding may be properly directed to encircle the secondary winding.

FIG. 3 is a graph drawn to a logarithmic scale which illustrates the flat response in the gain of the transformer over a wide frequency range. From an inspection of the curve of FIG. 3 it is seen that the transformer of the present invention has a gain of approximately 27 thousand over the frequency range of three cycles to approximately 400 cycles at which time the gain begins to decrease as the frequency increases.

In order to more fully understand the operation of this unique transformer it is necessary to consider the purpose or intended use of the transformer. The primary winding of the present transformer is constructed of heavy copper and has an extremely low resistance since the detector to which the primary is to be connected likewise has a very low resistance in the order of one milliohm. In a like manner the capacitance, a major factor in transformers, is at a minimum due to the utilization of a single turn primary which reduces, proportionately, the number of turns on the secondary winding. A suitable detector is a large single turn loop of heavy copper approximately 7 foot in diameter and is utilized to detect natural electromagnetic low frequency radiation. The signals sensed by such a detector generate a detection voltage above, but in the vicinity, of the natural thermal noise of the detector and the primary. The secondary winding of the transformer is connected to the grid of a suitable tube type amplifier tube. One of the purposes of the transformer is to step-up the voltage of the detector to the point where it can conveniently drive the amplifier. Remembering that the voltage detected by the detector is extremely low, the problem of the natural thermal noise of the tube must be overcome as well as the flicker effect of a vacuum tube. The flicker effect is known as the minute variations in the cathode current of thermionic vacuum tubes which may be caused by random changes in cathode activity or positive ion emission.

With the intended use of the transformer in mind, it is the purpose of this transformer to realize the maximum sensitivity and bandwidth from a low resistance detector at very low frequencies and to raise the detected voltage to a point where the thermal noise of the detector resistance exceeds the input noise of a vacuum tube to which the secondary winding of the transformer is connected. The ultimate sensitivity or minimum detectable signal of an electromagnetic detector is the alternating magnetic field intensity at which the induced voltage from the electromagnetic radiation equals the thermal noise of the detector. This maximum sensitivity is achieved in this transformer by maintaining the primary winding to a single turn thereby reducing the resistance to a minimum value and allowing detection of very small induced voltages.

The voltage thus detected must then be raised to the point where the voltage output of the secondary winding exceeds the thermal noise inherent in the input of the vacuum tube amplifier. This is required since the vacuum tube amplifier amplifies both the noise as well as the signal and in order to distinguish the information signal from the noise signal, it is desirable to raise the information signal voltage level to approximately four or five times the voltage level generated by the thermal noise of the tube. In this manner the detected signal voltage masks the inherent thermal noise and the sensitivity of the detector then is only limited by the unavoidable thermal noise of the detector and the primary winding of the transformer. Thermal noise voltage is proportional to the square root of resistance and for this reason the detector and the primary winding must be made to have as low a resistance as physically feasible which is accomplished by having a single turn primary constructed of heavy copper.

The flicker effect of a vacuum tube is inversely proportional to the frequency of the detected signal. To overcome the flicker effect the set number of turns of the secondary winding must be increased to raise the information signal voltage above the noise produced by the flicker effect of the vacuum tube. By increasing the number of turns of the secondary winding the voltage is stepped-up, however, this also increases the shunting capacitance of the transformer and limits the high frequency response obtainable from the detector. By equating the thermal noise of the detector and primary to the flicker noise of the tube at about four cycles per second it is possible to obtain the maximum sensitivity and bandwidth from the detector. Signals from about a half cycle per second are able to be detected while at the same time not unduly limiting the high frequency response of the detector.

Normally high step-up transformers are subject to stray high frequency electromagnetic radiation as well as feedback from the amplifier circuit and generally require a damping impedance to be placed in the secondary winding of the transformer to compensate for this undesired effect at the natural resonant point. This impedance placed across the secondary winding has the added disadvantage that the available signal voltage is substantially reduced. By utilizing in the present invention a single turn large mass copper primary winding and encasing therein the secondary winding and magnetic core, it is possible to shield the secondary winding from the stray electromagnetic radiation since radiation is absorbed by the primary winding. Since the high frequency eddy currents induced in the primary winding create only a surface disturbance in the magnetic field, the high frequency field does not couple with the secondary winding thereby eliminating the high frequency effect.

The transformer of the present invention is ideally suited for use with a vacuum tube amplifier since the noise of a vacuum tube is in the magnitude of 1,500 ohms at high frequencies to one megohm at one cycle per second while the capacitance reactance is very high, about 10,000 megohms at one cycle per second and one megohm at high frequencies. Since capacitance reactance generates no thermal noise it is ideally suited to be utilized with the present transformer. A much lower step-up transformer would be required for a transistor, however, transistors are not suited for the present application due to the high input resistance and the high semiconductor noise.

The contact surfaces between the cover plate 6 and the cup-shaped member 17 can be coated with silver to increase the conductivity since both silver and its oxide are conductive. For the same reason the two primary winding lug connections are silver plated to reduce their contact resistance. The screws 7, utilized to maintain the cover plate 6 in contact with the cup-shaped member 17, also perform the added function of insuring good electrical contact between the two members as well as applying a uniform and even, though slight, pressure on the secondary winding to increase the magnetic coupling between the primary winding and the secondary winding.

The present transformer also has application in the study of human and animal nerve reactions. It is known that the nerves generate a small electrical electromagnetic field and that by eliminating the effect of normal electromagnetic radiation by the use of oppositely wound coils, a tiny search coil, having resistance of approximately 1 milliohm, the coil is able to detect the field generated by the nerve. The output from this detector would be operable with the transformer of the present invention since the resistance of the primary winding is not increased. From this it is seen that the requirement of the detector need not be that of the large low resistance detector but can be a small detector and that the controlling factor is the low resistivity of the detector itself.

The present transformer by the use of the single turn, large mass, low resistance primary winding completely enclosing the secondary winding and the magnetic core within itself produces a high gain transformer suitable for driving a tube amplifier by a very low voltage detector. The enclosure of the secondary winding within the high mask primary winding eliminates the effect of capacitive stray electromagnetic fields, thereby eliminating feedback problem. The close coupling of the primary and secondary winding, together with the aforedescribed characteristics, mutually cooperate to produce a transformer which produces a flat gain over a wide frequency range as illustrated in FIG. 3.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. A high ratio vacuum tube input transformer comprising:

an open ended cup-shaped single turn primary winding having a substantially solid center projection and a solid side wall tapered at the inside of the uppermost portion,

a solid cover plate having a tapered peripheral portion conforming to said side wall and held wedged in tight electrical contact with the side wall and being electrically insulated from the center projection,

said primary winding and said cover plate forming a toroidal shaped cavity of conductive solid materials and having an ohmic resistance in the order of 1 milliohm whereby the attenuation of frequencies below 400 cycles is reduced, said solid side wall and solid cover plate being absorbtive to eddy currents whereby currents induced in the primary having frequencies above 2000 cycles per second are absorbed as eddy currents,

a pair of input terminals connected to said cover plate and to said center projection respectively,

a toroidal shaped highly permeable core,

a multi-turn secondary winding encircling said magnetic core, said magnetic core and said secondary winding being enclosed completely within the cavity, and shielded from high frequency currents by the primary winding and cover plate,

a pair of output terminals,

and means connected to said secondary winding and said pair of output terminals for conducting the voltage of said secondary winding to said output terminals.

2. Apparatus as recited in claim **1** wherein the connecting surfaces of each of said pair of input terminals is conical and complementary in shape to a respective hole in said cover plate and is maintained in compression by a compressing means.

3. Apparatus as recited in claim **1** wherein a pair of insulative coverings completely enclose both the interior and exterior surfaces of said secondary winding.

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