Oct. 15, 1968 R. H. RUSSELL ET AL 3,406,364

TOROID TRANSFORMER ELECTROSTATIC SHIELD

Filed March 1, 1965

FIG. 3.

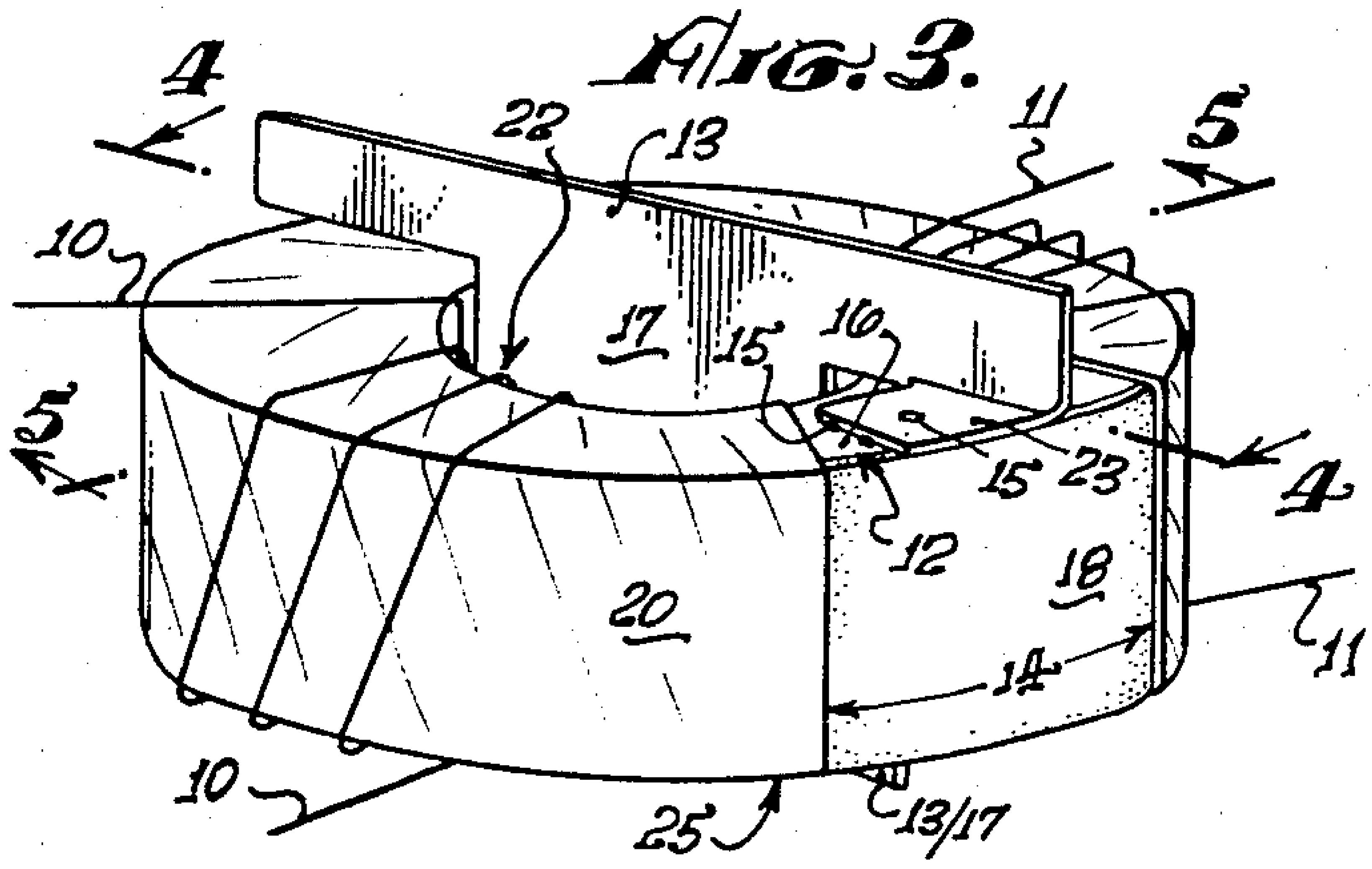


FIG. 1.

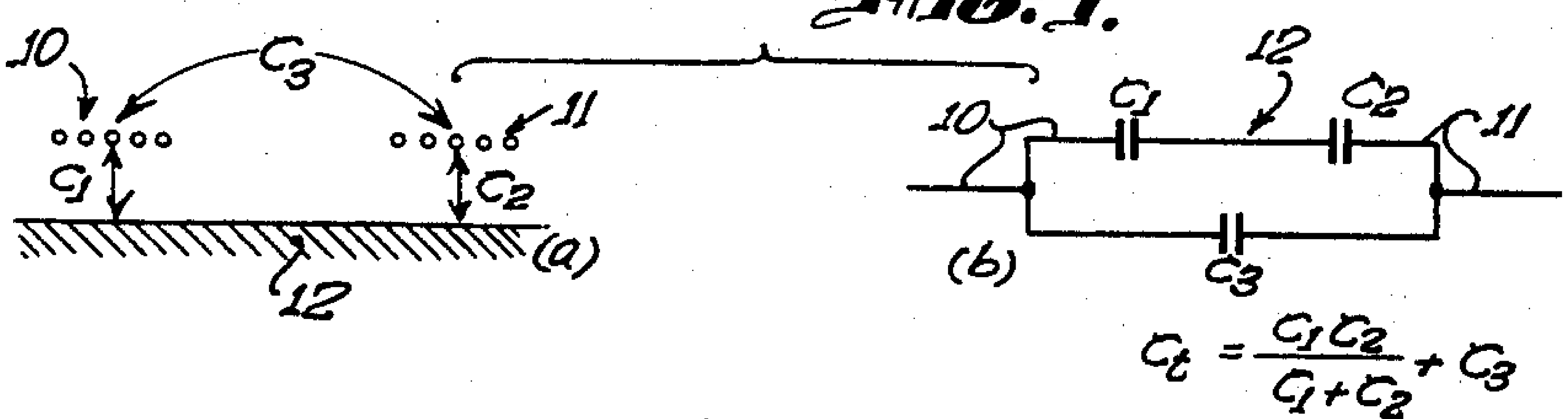


FIG. 2.

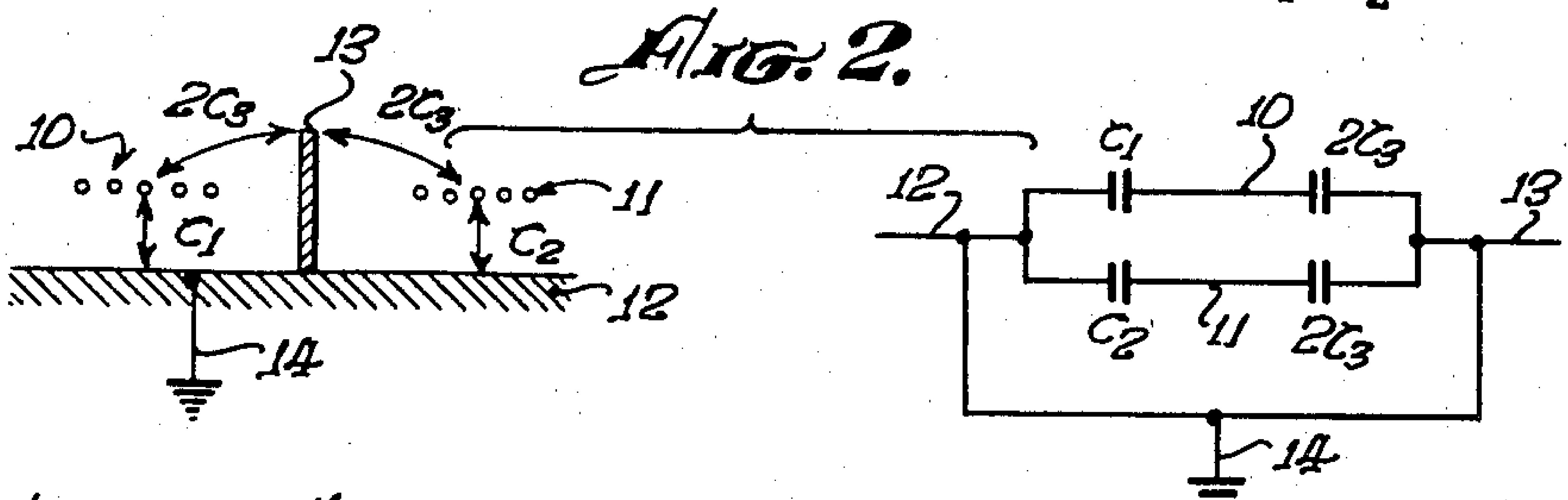


FIG. 4.

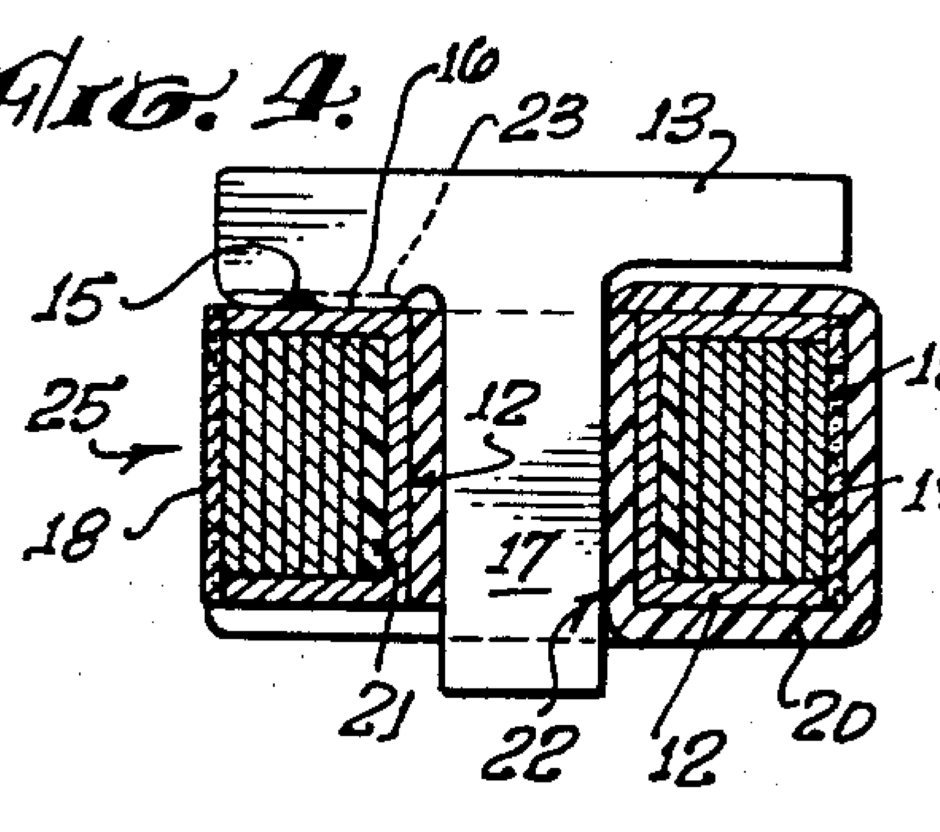
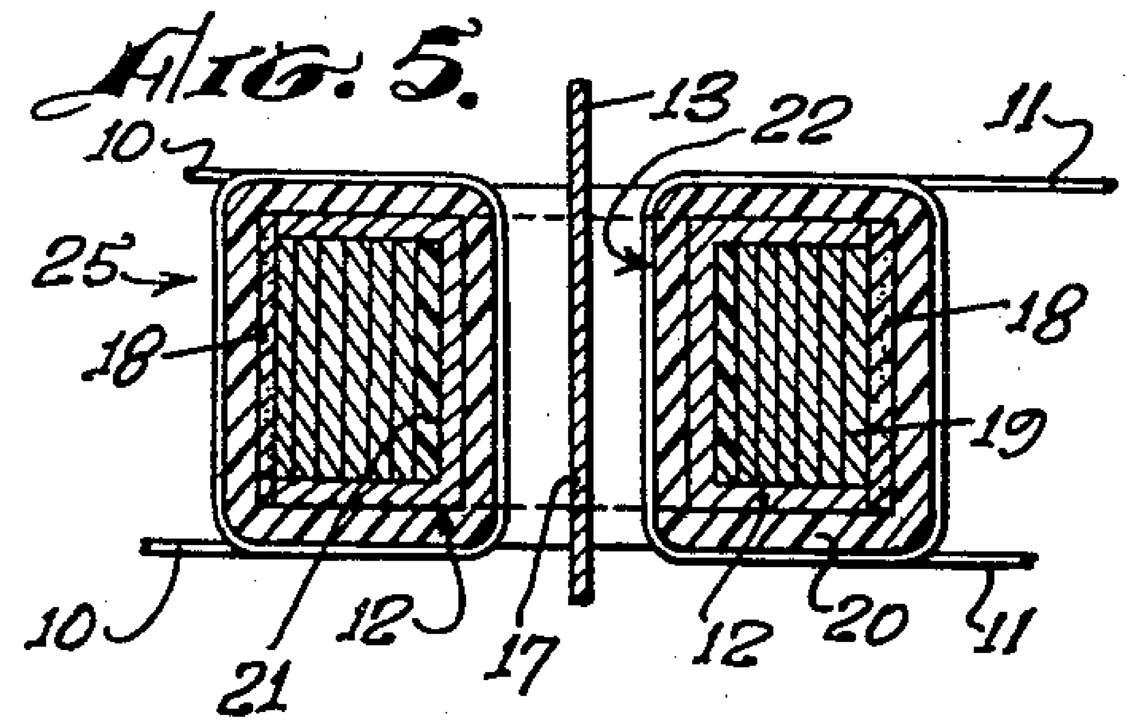


FIG. 5.



INVENTORS.
ROBERT H. RUSSELL,
DONALD BOYKO,
JOHN A. GILBERT,

BY THEIR ATTORNEYS
Spensley & Horn.

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TOROID TRANSFORMER ELECTROSTATIC SHIELD

Robert H. Russell, Altadena, and Donald Boyko and John A. Gilbert, Pasadena, Calif., assignors to Electro-Optical Systems, Inc., Pasadena, Calif., a corporation of California

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This invention relates to toroid transformers and more particularly to a novel interwinding shield for eliminating the electrostatic coupling between primary and secondary windings of small toroid transformers.

Recent developments in materials in the prior art have made it possible to provide electrostatic shielding for small torroid transformers. Under the usual conditions of use of such transformers any shielding between windings would increase the interwinding and winding-to-core capacitances because of the small dimensions involved.

In the prior art a transformer as small as ¾″ in diameter could be shielded only with great difficulty. The most recent technique above referred to consisted of the steps of painting a conductive coating on the toroid core to provide the shielding surfaces, following this with a layer of insulative material for several alternate layers of the shield and insulation upon the core. To achieve effective shielding by this prior art technique many layers of conductive paint and insulative material had to be used as above described. The result was accomplished at a substantial cost in time and materials and with less than a desirable degree of reliability. The increase in rate of failure was as high as five times as great as for an unshielded toroid transformer.

The present invention contemplates a novel means whereby the electrostatic shielding between the windings of a small toroid transformer may be achieved without any of the attendant difficulties which were characteristic of the only other known prior art method. No conductive paint and insulative materials in alternate layers intervene between the winding and core. The new technique according to this invention can be implemented with little mechanical difficulty in inserting the shield.

According to the present invention the windings of the toroid are made very close to the core. The core is wound about, but insulated from, a toroidal conductive steel bobbin. In the absence of a ground reference, capacitance between each winding and the core may be considered as series capacitors and the capacitances between primary and secondary windings in parallel with the series capacitances. Shielding material is added across the toroid, perpendicularly to the plane of the toroid, and is connected to the conductive toroid bobbin electrically. The result is an electrostatic shield between primary and secondary windings, which are wound about the toroid on either side of the shielding material, and due to the shield and its connection to the bobbin, remaining coupling capacitance between the primary and secondary windings is reduced to a minimum.

Electrostatic isolation achieved with the present invention is the result of using the conductive bobbin as a direct interwinding shield with the electrostatic shield insert connected electrically at a single point to the toroid bobbin. The effect of inserting the shield is to provide a ground reference return path between the windings which inhibits the effects of potential changes on the primary electrostatically inducing potential changes in the secondary.

The electrostatic shield may be utilized as a low impedance dissipation path for noise currents.

Fabrication of toroid transformers according to the present invention is simplified as compared to the prior art transformers because windings can now be made continuously and without the danger of injury to layers in the process of applying insulative paints or coatings to the windings. Windings are accessible and not obscured by subsequently applied layers as in the prior art. There is no mechanical interference between windings, as in prior art toroid transformers, when the electrostatic shield is added.

The toroid transformers, implemented in accordance with this invention, are particularly useful in direct-current-to-direct-current converters where electrostatic shielding is essential for interference-free and low-noise operation.

Accordingly it is an object of this invention to provide a novel improved and more reliable toroid transformer with electrostatic shielding between the primary and secondary windings thereof for low-noise and interference-free operation in electric circuits.

It is another object of this invention to provide in toroid transformers of small size, an effective electrostatic shielding means which is both reliable and presents no mechanical interference between windings.

It is further an object of this invention to provide a novel electrostatic shield for a toroid transformer wherein the shield is across the toroid and electrically connected to one point therein, the primary and secondary windings of the transformer being respectively wound on either side of the shield insert about the toroid.

It is still another object of this invention to provide in a toroid transformer a conductive toroid with an electrostatic shield inserted across the toroid, the shield being electrically in contact with said toroid at one point thereon.

It is a still further object of this invention to provide in a toroid transformer an effective electrostatic shield between primary and secondary windings including a thin toroid bobbin of conductive material with a wrapped ferro-magnetic core upon which is wound insulative tape completing less than a full circumferential turn of the bobbin, and an electrostatic shield inserted perpendicularly to the plane of the bobbin across the bobbin and in contact with the conductive material thereof at the point of incompletion of said turns of insulative core wrapping material.

These and other objects of this invention will become more clear from the specification which follows in which a preferred embodiment of the invention is disclosed. The embodiment shown and described should be taken as being merely illustrative of the invention and not limited to the embodiment described since those skilled in the arts appertaining hereto will be able to devise other embodiments in the light of the teachings herein when taken together with the drawings and the appended claims.

In the drawings:

FIGURE 1 is a representation of the relationship between the windings of a transformer and the core with respect to the capacitances between them;

FIGURE 2 shows the relationship of capacitances when this invention is employed;

FIGURE 3 is a perspective drawing of a toroid transformer in accordance with the present invention;

FIGURE 4 is a cross-section through 4—4 of FIGURE 3; and

FIGURE 5 is a cross-section through 5—5 of FIGURE 3.

Referring now to FIGURES 1 and 2 for an understanding of the capacitive relationships between primary, secondary and core of transformers generally, and a toroidal transformer in particular, the figures show a primary winding **10** in a mechanical schematic form and a secondary winding **11** spaced by some dielectric means above a core **12**. Primary winding **10** forms the equivalent of one plate of a capacitor C1 with core **12**. Secondary winding **11** forms a capacitor C2 with core **12**. Between primary **10** and secondary **11** a third capacitor C3 is formed, the latter being the stray capacitance between the windings without an added shield in accordance with this invention.

In (*b*) of FIGURE 1 the electrical circuit equivalent of the capacitive relationships above described is shown and can be seen to represent a pair of capacitors C1 and C2 in series, with a capacitor C3 connected across the series pair as a parallel element therewith. The resulting capacity C_t between primary and secondary can be seen to be

$$C_t=\frac{C1\times C2}{C1+C2}+C3$$

The schematic representation in FIGURE 2 shows how a shield according to this invention interposed between primary winding **10** and secondary winding **11** changes the capacitance configuration. Now the interwinding capacitance can be represented by two capacitances, each $2C_3$. Each capacitor, $2C_3$, is between a winding and shield **13**. Shield **13** is in the form of a T-shaped plate which is more fully described hereinbelow, and which is inserted in the core of a toroid transformer as further described below for the purpose of intersecting the direct stray coupling capacitances between primary and secondary.

When shield plate **13** is connected to a low impedance ground return or zero reference path any electrostatic field from either primary or secondary winding generates a charge movement only in said shield plate and not across to the other winding, thereby eliminating first order electrostatic coupling between windings. That is, the interwinding capacitance is eliminated. In a typical case the reduction in the interwinding capacitance achieved was from 12 pf. to .75 pf.

The physical structure of a transformer according to this invention is shown in FIGURE 3 in a perspective view. Sections taken through 4—4 of FIGURE 3 and 5—5 of FIGURE 3 are shown in FIGURES 4 and 5 respectively. In referring to FIGURES 3–5 the reference characters used correspond with those in the other figures and are consistent in that like items employ like reference characters in each figure.

In FIGURES 3–5 a bobbin **12** can be seen to have a spool-like shape. Bobbin **12** is of a conductive material and preferably of a conductive origin such as steel or copper and the like. A flat thin tape or ribbon of insulative material **21** coats or covers the entire inside of bobbin **12** including the inner surfaces of the bobbin flanges. Then about the bobbin **12** a ferromagnetic ribbon **19** is wound circumferentially until bobbin **12** is filled. Thus ribbon or tape **19** forms a core with shielding provided by the spool-like structure of bobbin **12**. An outer insulative ring of material **18** (which may be cardboard or some other covering for the ferromagnetic ribbon or tape **19**) is wound, circumferentially.. Finally a thin insulative tape **20** is wound around the resulting toroid ring save for the area shown by arrows **14** which leaves the conductive surface of bobbin **12** exposed as at **16**.

The bobbin **12**, ferromagnetic tape **19** wound thereon, protective covering **18** and insulative wrap around tape **20** form a toroidal transformer core **25**. On an axis 90° removed in one direction from the gap **14** a primary winding **10** is placed on core **25**; and opposite a secondary winding **11** is wound.

A T-shaped electrostatic metallic shield **13** is inserted in the central aperture **22** of core **25**, as indicated at **17**. Shield **13** has a bent over tab **23** on an end thereof which is welded or otherwise made to electrically contact bobbin **12** as shown at **15**, in the gap area **14–16** as previously described.

The resulting toroid transformer configuration can thereby be seen to comprise the conductive bobbin **12** which may be of steel upon which is wound circumferentially a ferromagnetic tape **19** filling bobbin **12** to its periphery. Wound about the resulting toroid core **25** is an insulative tape **20** which does not completely cover the bobbin **12** but leaves exposed an area **14** to which electrically conductive contact can be made as at **15**. A T-shaped shield **13/17** is inserted in the toroid well at **22** and a tab **23** thereon is welded at **15** to the exposed portion **16** of bobbin **12**. A primary winding **10** and a secondary winding **11** are wound about core **25** respectively on opposite sides of shield **13/17**. The material of shield **13/17** is conductive, such as copper, brass, or aluminum, which will prevent stray capacitive coupling of electrostatic charges across from primary **10** to secondary **11**. Since the pertinent magnetic coupling is through the core **25**, the shield **13/17** does not affect any but the stray coupling.

The shield **13/17**, being positioned between primary **10** and secondary **11**, and electrically tied to the conductive bobbin **12**, is grounded in use as indicated at **14** in FIGURE 2, so that shield **13/17** is, in fact, at ground return reference and provides a low impedance path for any electrostatic charge generated by primary winding **10** or secondary **11** preventing the transfer of electrostatic noise or interference pulses between primary **10** and secondary **11**.

What is claimed is:

1. In a toroid transformer, the combination of:
   a torodial bobbin of conductive material;
   a ferromagnetic tape wrapped circumferentially about and insulated from said bobbin of conductive material;
   insulation material wrapped upon said bobbin, leaving only a small space of said conductive material of said bobbin exposed;
   an electrostatic shield plate inserted across the diameter of said bobbin, making electrical and mechanical contact with said conductive material of said toroidal bobbin only at said exposed small space, said shield being in a plane perpendicular to the plane of the circumference of said bobbin, said bobbin, said ferromagnetic tape, and said insulating material forming an insulated toroidal core with said shield inserted therein;
   a primary winding wound on said core on one side of said shield; and a secondary winding wound on said core on the other side of said shield opposite said primary winding,
   whereby, the interwinding capacitances between said primary winding and said secondary winding are a minimum and said shield thereby provides a maximum interwinding electrostatic shielding against electrostatically induced potentials between said windings to reduce interference and noise that may be otherwise generated in the use of said transformer.

2. An improved toroid transformer, comprising:
   a conductive toroidal bobbin having a central aperture;
   a ferromagnetic tape insulatively wrapped upon said bobbin;
   insulation material wrapped about said bobbin, with said ferromagnetic tape thereon, leaving only a small space of said conductive material of said bobbin exposed;
   an electrostatic shield plate inserted in said central aperture across the diameter of said bobbin, and adapted to make electrical contact with said conductive bobbin only at said exposed small space, said shield being in a plane perpendicular to the circumferential plane of said bobbin, said bobbin, said ferromagnetic tape, and said insulation material forming an insulated toroidal core with said shield inserted therein;

a primary winding wound on said core on one side of said shield; and

a secondary winding wound on said core on the other side of said shield;

whereby the interwinding capacitances between said primary winding and said secondary winding are minimized and said shield provides maximum electrostatic shielding against electrostatically induced potentials between said windings to reduce interference and noise that may be otherwise generated in the use of said transformer.

3. In a toroid transformer, the combination of:

a toroidal bobbin of conductive material;

a ferromagnetic tape wrapped circumferentially about and insulated from said bobbin of conductive material,

insulation material wrapped upon said ferromagnetic tape and said conductive bobbin leaving only a small space of said conductive bobbin exposed;

an electrostatic shield plate inserted across and perpendicular to the diameter of said bobbin, in conductive contact therewith;

said bobbin, said ferromagnetic tape, and said insulation material forming an insulated toroidal core with said shield inserted therein;

a primary coil wound on said core on one side of said shield; and a secondary coil wound on said core on the other side of said shield opposite said primary coil;

whereby, the interwinding capacitances between said primary winding and said secondary winding are minimized and said shield provides shielding against electrostatically induced potentials between said windings to reduce interference and noise that may be otherwise generated in the use of said transformer.

4. In a toroid transformer, the combination of:

a toroidal bobbin of conductive material;

a ferromagnetic tape wrapped circumferentially about and insulated from said bobbin of conductive material;

insulating material surrounding said ferromagnetic tape and said conductive bobbin leaving only a small space of said conductive bobbin exposed, said tape and said bobbin comprising an insulated toroidal transformer core;

an electrostatic shield plate inserted across the diameter of said core in electrical contact with the conductive material of said bobbin;

a primary winding on said core on one side of said shield plate; and

a secondary winding on said core on the other side of said shield plate,

whereby the interwinding capacity is minimized and electrostatic coupling between said primary winding and said secondary winding eliminated thereby to shield said windings from electrostatically induced charges from one of said windings to the other, and reduce interference or noise voltages that may otherwise be developed in said windings in the use of said transformer.

5. In a toroid transformer the combination of:

a toroidal core comprising a bobbin of conductive material having a ferromagnetic tape wrapped circumferentially about and insulated from said bobbin of conductive material;

insulating material surrounding said ferromagnetic tape and said conductive bobbin having only a small space of said conductive bobbin exposed;

an electrostatic shield inserted perpendicularly to the plane of said core across the diameter of said core making electrical and mechanical contact at said exposed small space with said conductive material of said bobbin;

a primary winding on said toroidal core over said ferromagnetic tape wrapping on one side of said shield; and,

a secondary winding wound on said toroidal core over said ferromagnetic tape wrapping on the other side of said shield diametrally opposite said primary winding,

whereby the interwinding capacitances between said primary winding and said secondary winding are reduced, and said electrostatic shield provides a maximum interwinding electrostatic shielding to reduce interference and noise that may otherwise be generated by said transformer in use thereof.

6. A toroid transformer comprising the combination of:

a toroidal core formed by a bobbin of conductive material wrapped circumferentially with a ferromagnetic tape;

insulating material surrounding said ferromagnetic tape and said conductive bobbin leaving only a small space of said conductive bobbin exposed;

an electrostatic shield inserted perpendicularly to the plane of said core across the diameter of said core in electrical contact with said conductive material at said exposed small space;

a primary winding on said toroidal core on one side of said shield; and,

a secondary winding on said toroidal core on the other side of said shield diametrally opposite said primary winding,

whereby the interwinding capacitances between said winding is reduced by said electrostatic shield to thereby provide a maximum interwinding electrostatic shielding for reducing interference and noise that may otherwise be generated by said transformer in use thereof.

7. A toroid transformer comprising the combination of:

a toroidal ring of conductive material wrapped circumferentially about with a ferromagnetic tape, said tape insulated from said conductive ring;

insulating material surrounding said ferromagnetic tape and conductive ring leaving only a small space exposed;

an electrostatic shield inserted across the diameter of said ring in electrical contact with said conductive material at said exposed small space;

said shield being in a plane perpendicular to the plane of said ring;

a primary winding wound on said toroidal ring over said ferromagnetic tape on one side of said shield;

a secondary winding wound on said toroidal ring over said ferromagnetic tape on the other side of said shield diametrally opposite said primary winding; and

whereby the interwinding capacitances between said primary winding and said secondary winding is minimal and said shield thereby provides a maximum interwinding electrostatic shielding to reduce interference and noise that may otherwise be generated by said transformer in use thereof.

8. In a toroid transformer the combination of:

a toroidal ring of conductive material;

a ferromagnetic tape wrapped circumferentially about said conductive toroidal ring; insulation material wrapped upon said ferromagnetic tape and said conductive ring leaving only a small space of said conductive material of said toroidal ring exposed;

an electrostatic shield inserted across the diameter of said ring making electrical and mechanical contact at said exposed small space with said conductive material of said toroidal ring; said shield being in a plane perpendicular to the plane of said ring;

a primary winding insulatively wound on said toroidal ring over said ferromagnetic tape wrapping on one side of said shield; and, a secondary winding wound insulatively on said toroidal ring over said ferromagnetic tape wrapping on the other side of said shield diametrally opposite said primary winding;

whereby the capacitances represented by said primary winding to said toroidal ring, said secondary winding to said toroidal ring, said primary winding to said electrostatic shield and said secondary winding to said electrostatic shield result in a minimal interwinding capacitance, and said shield thereby provides a maximum interwinding electrostatic shielding against electrostatically induced potentials between said winding to reduce interference and noise that may otherwise be generated by said transformer in use thereof.

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LEWIS H. MYERS, *Primary Examiner.*

T. J. KOZMA, *Assistant Examiner.*