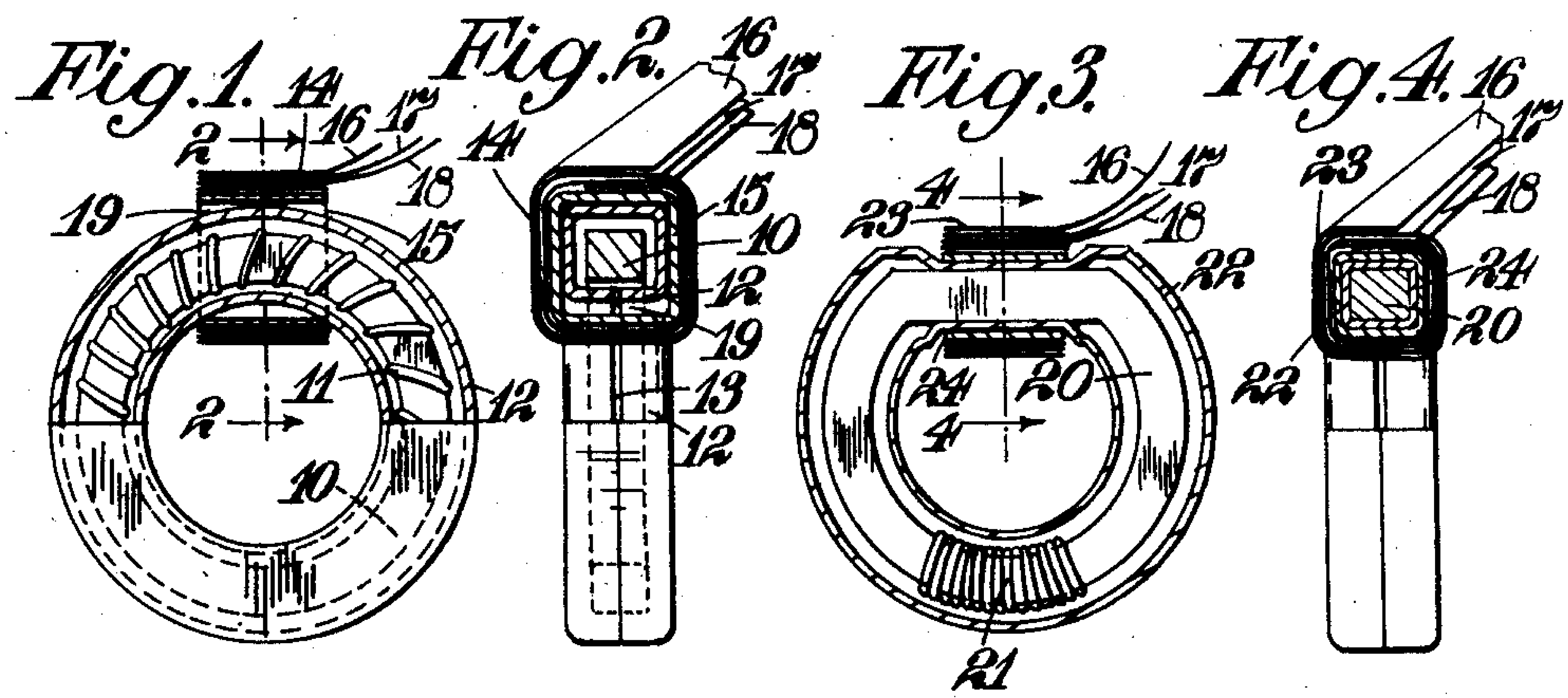
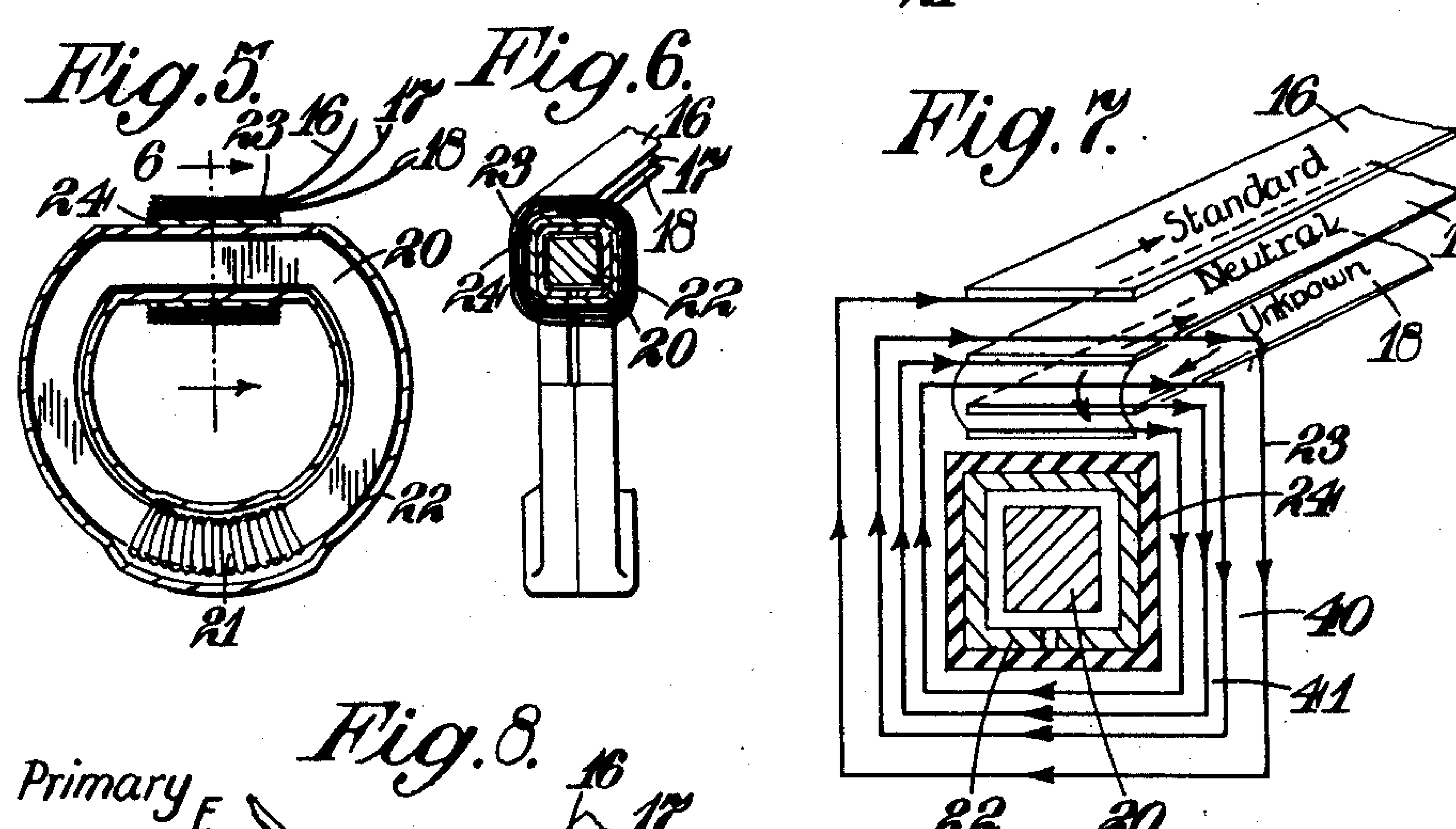
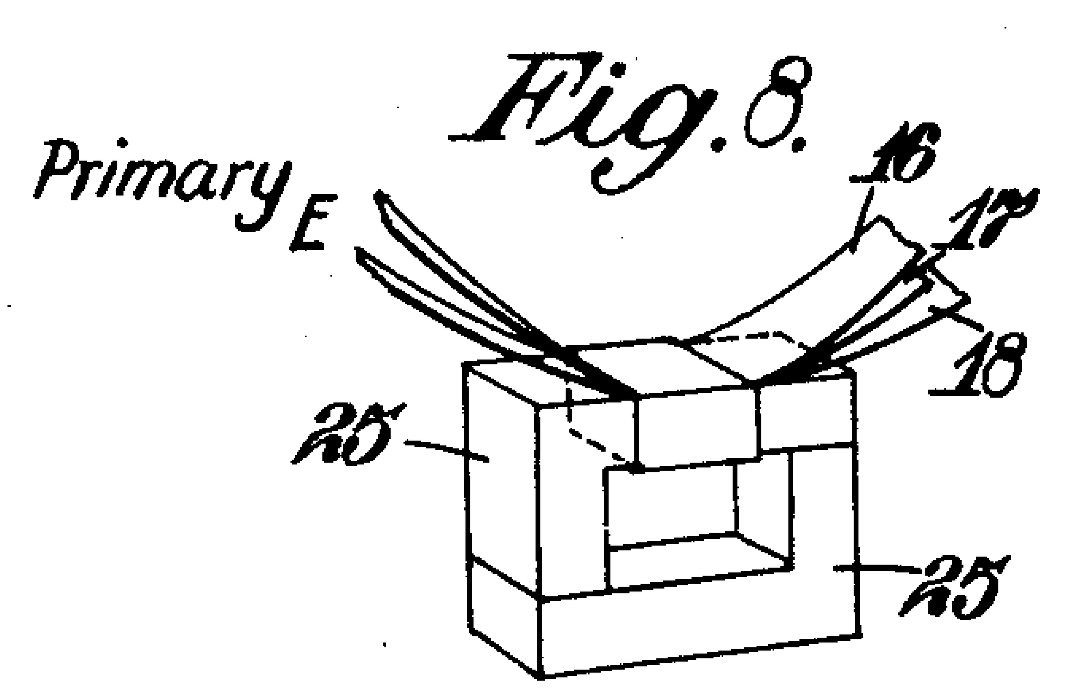
Nov. 17, 1953 R. CALVERT 2,659,845

HIGH-FREQUENCY ALTERNATING CURRENT TRANSFORMER

Filed Feb. 13, 1950 4 Sheets-Sheet 1







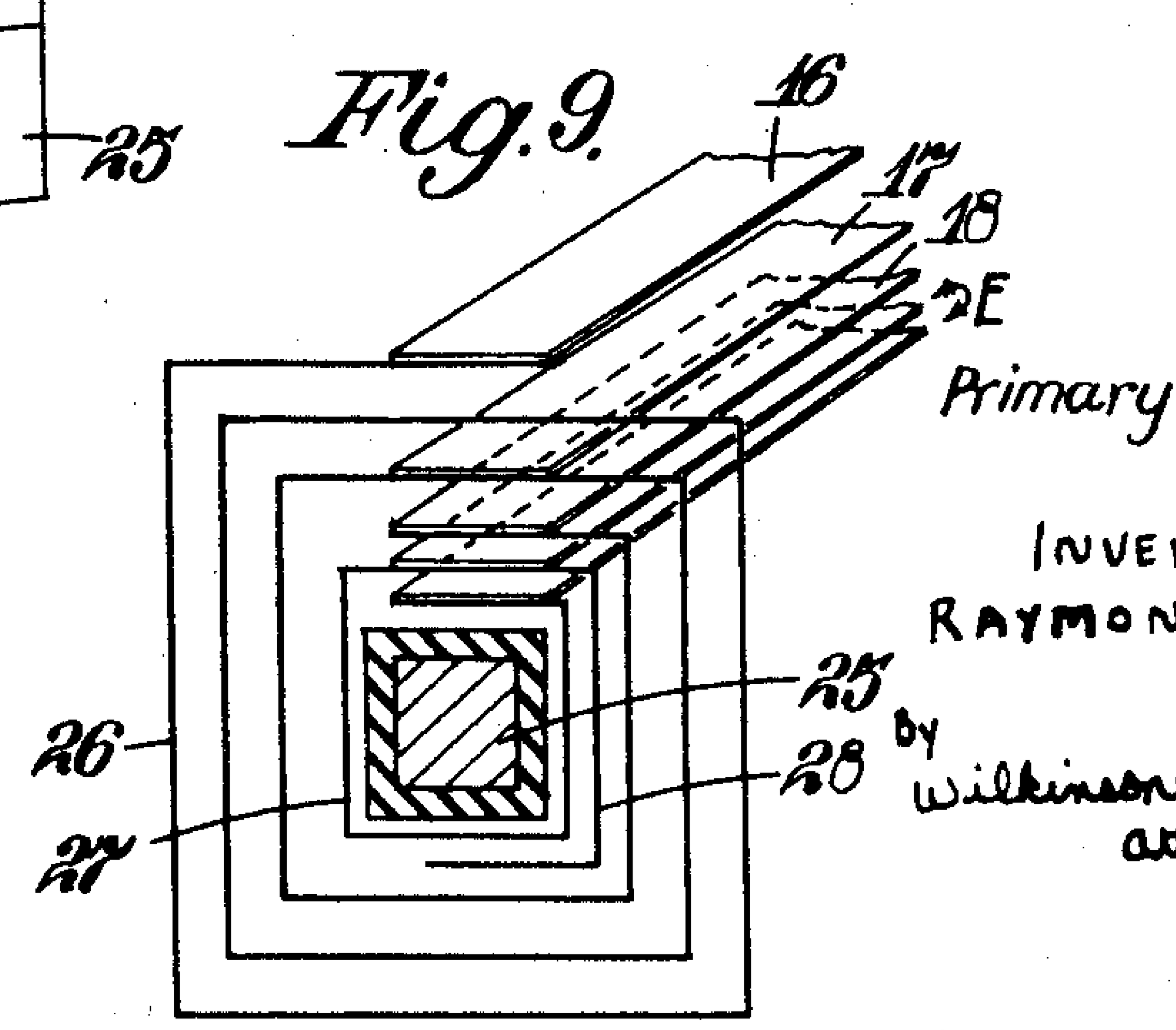


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Fig. 10.

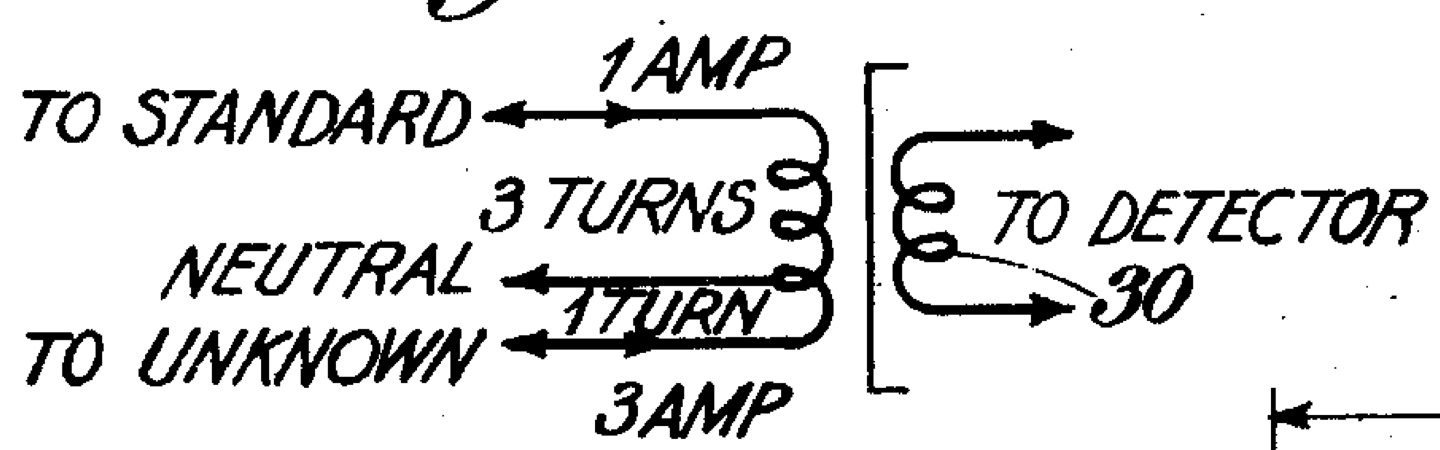


Fig. 11.

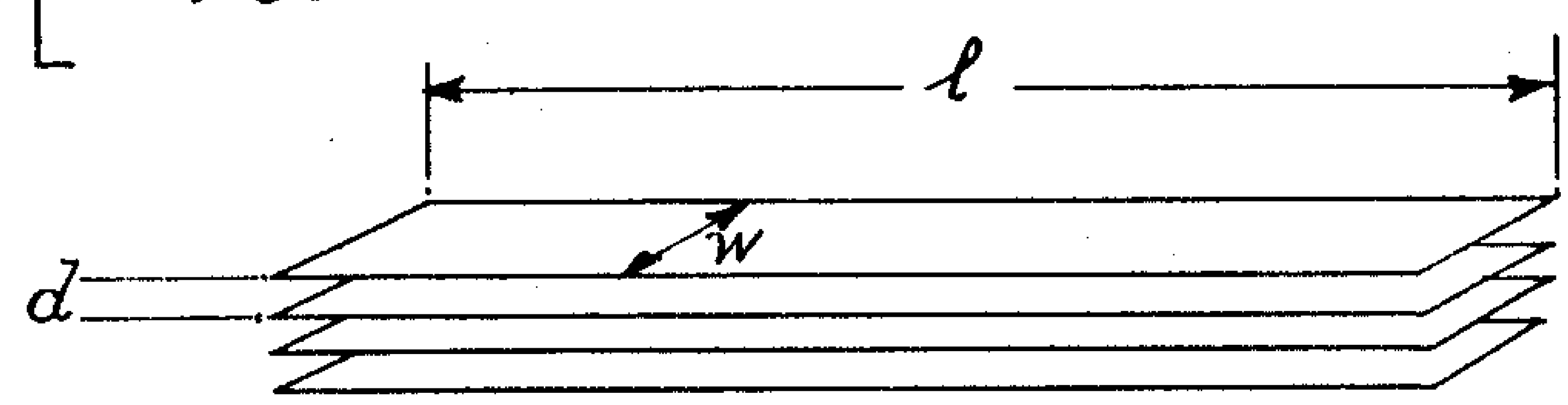


Fig. 12a.

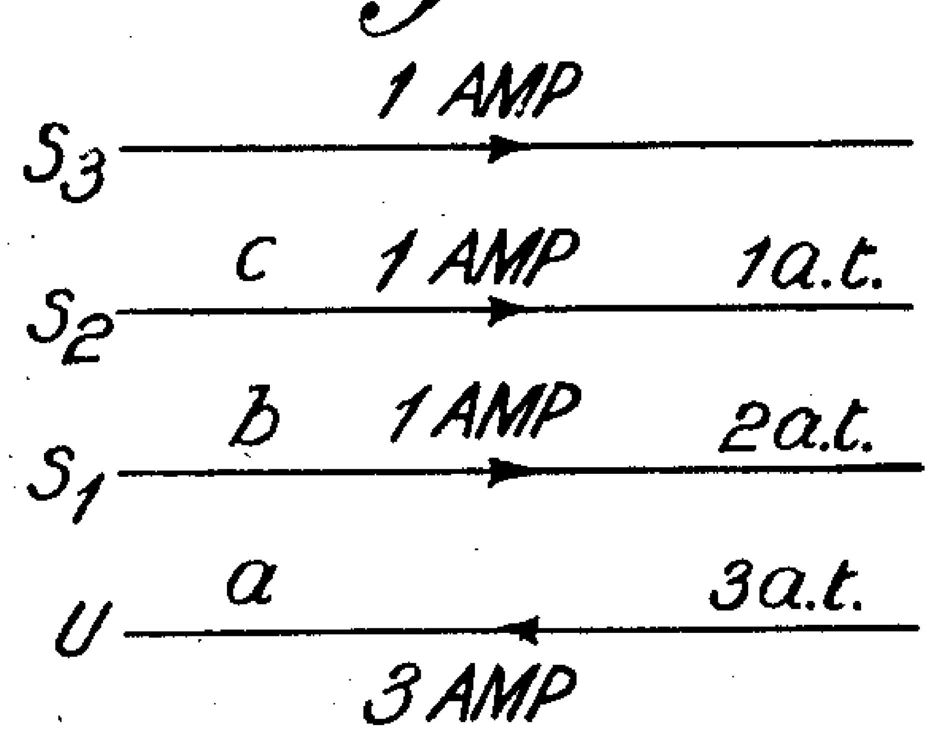


Fig. 12b.

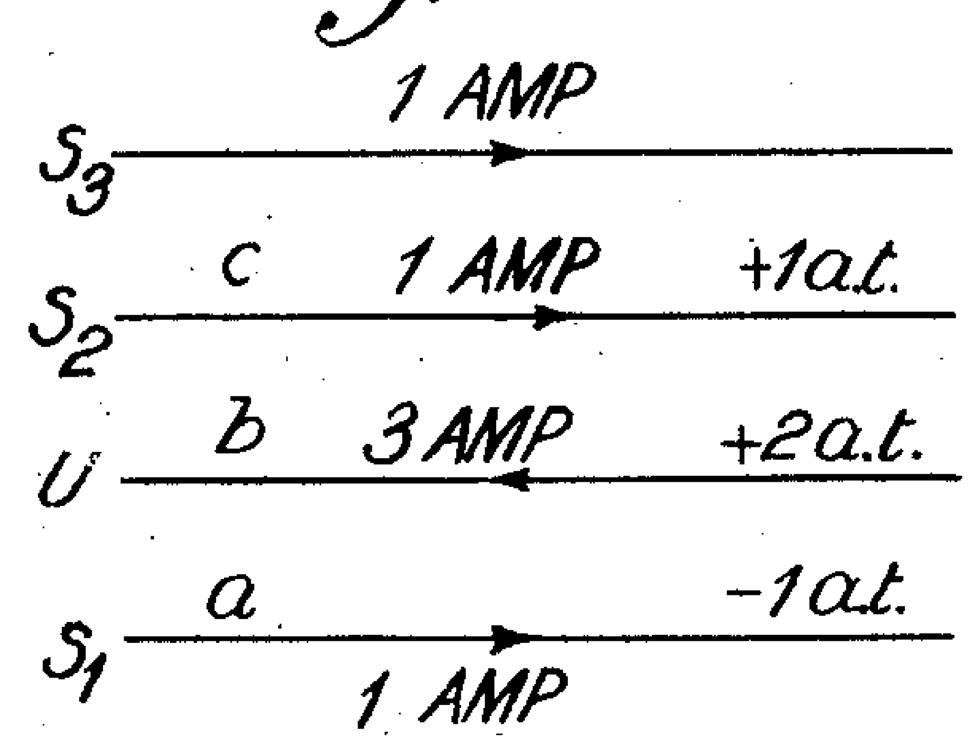


Fig. 12c.

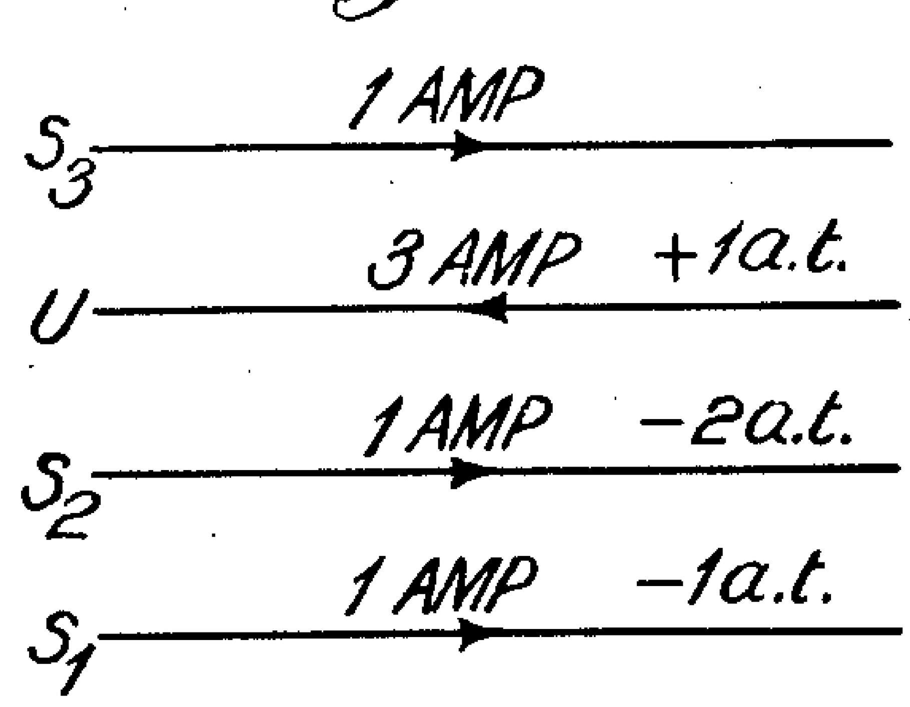
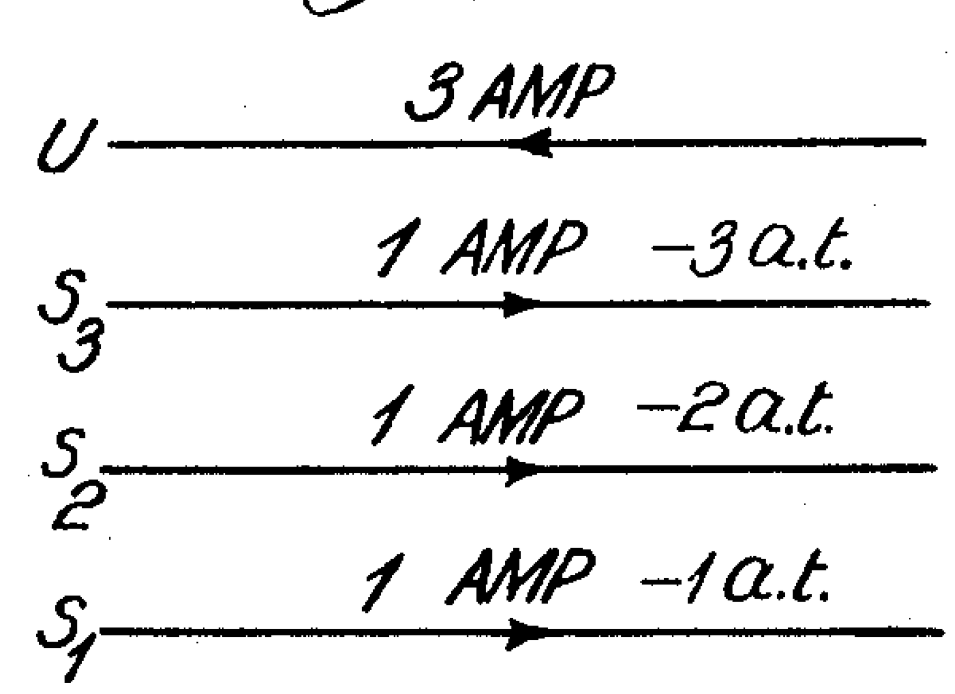


Fig. 12d.



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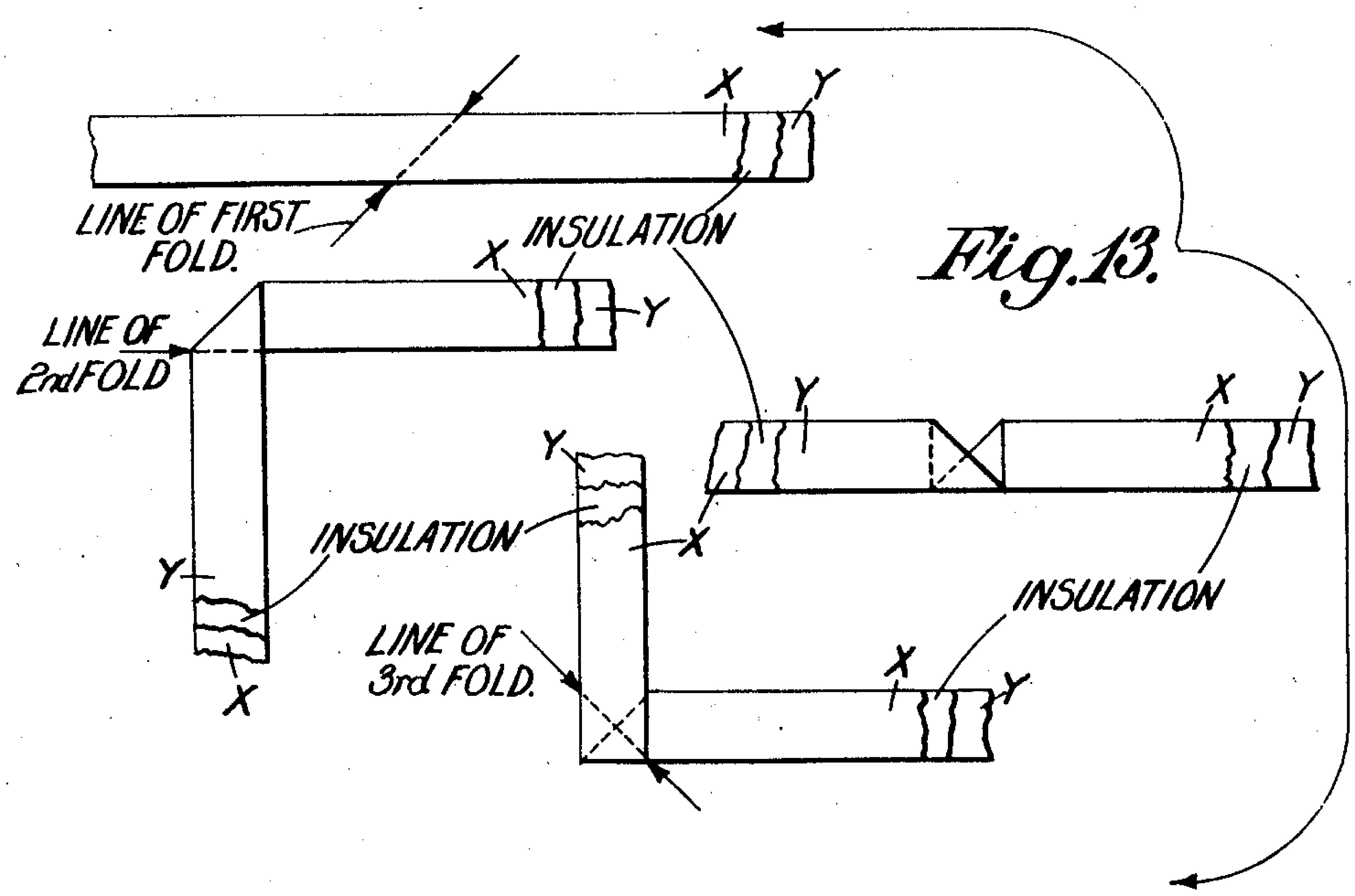

Fig. 13.

Fig. 14a.

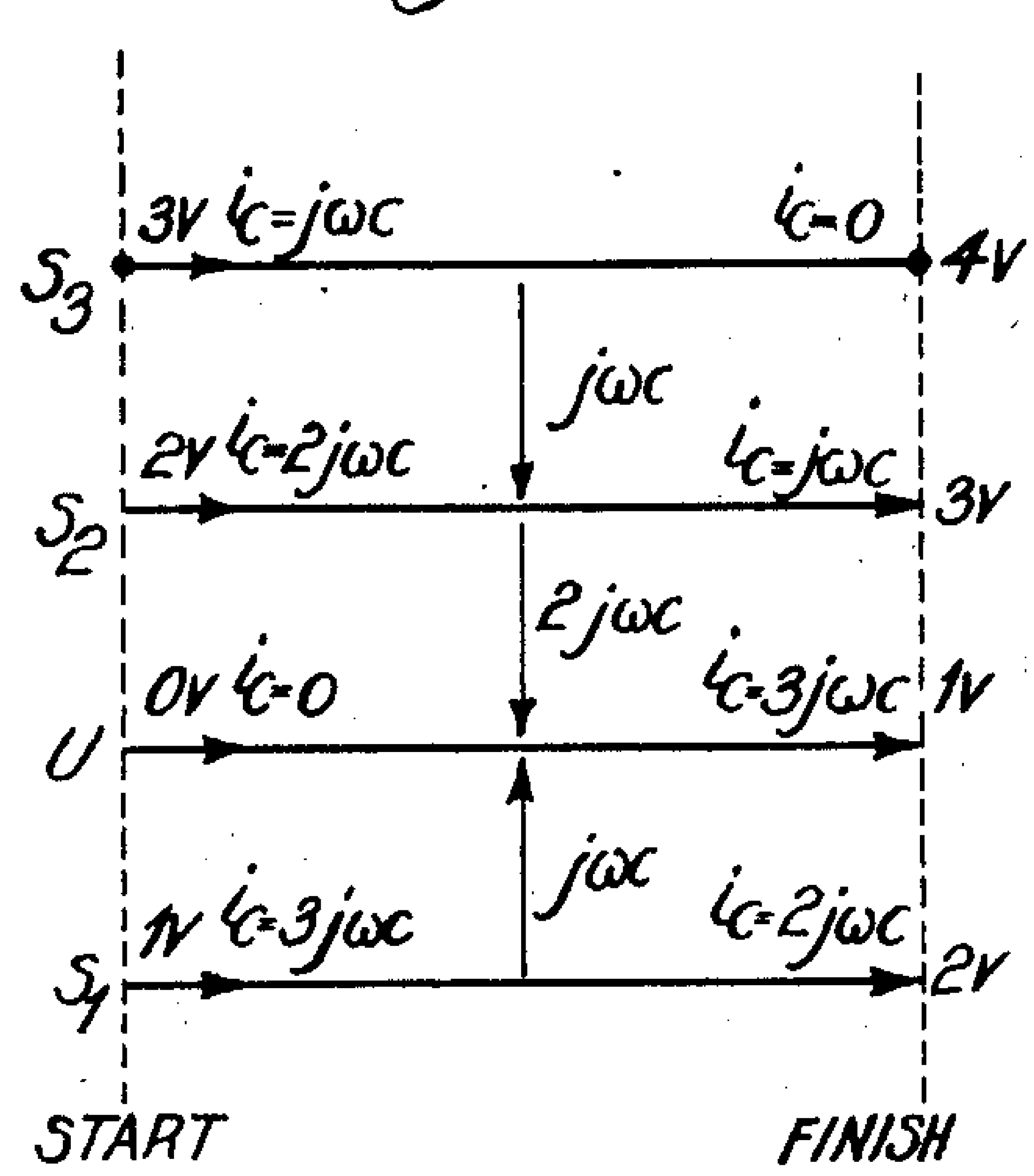

Fig. 14b.

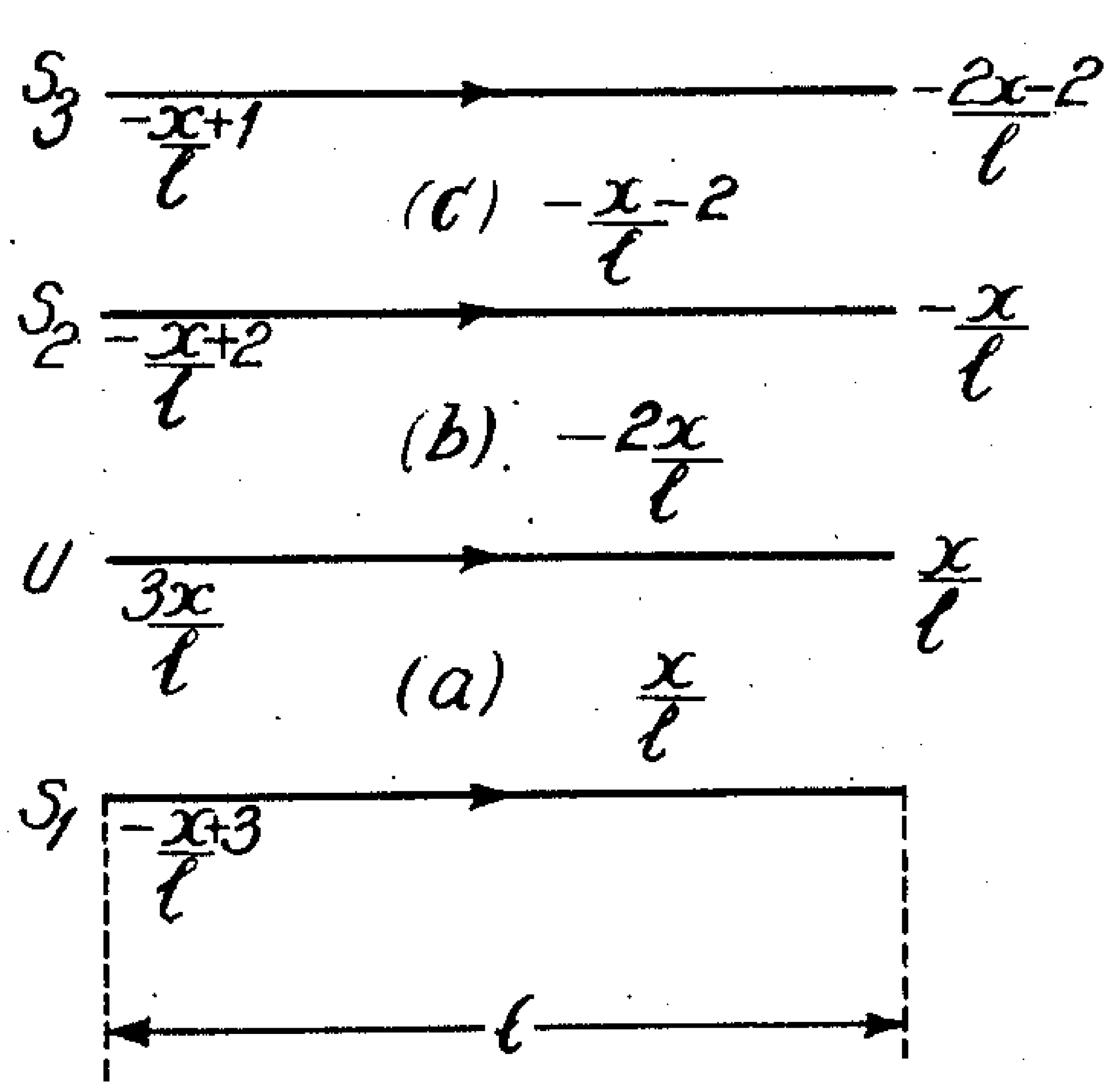

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Fig. 15a.

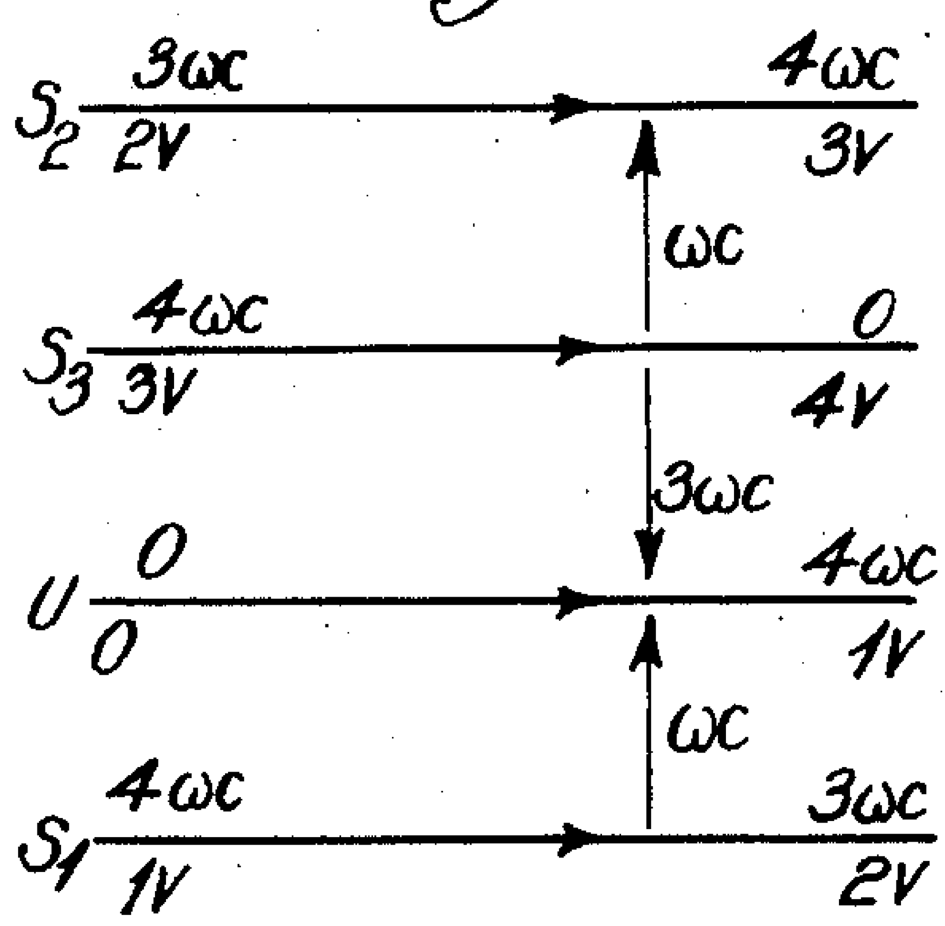


Fig. 15b.

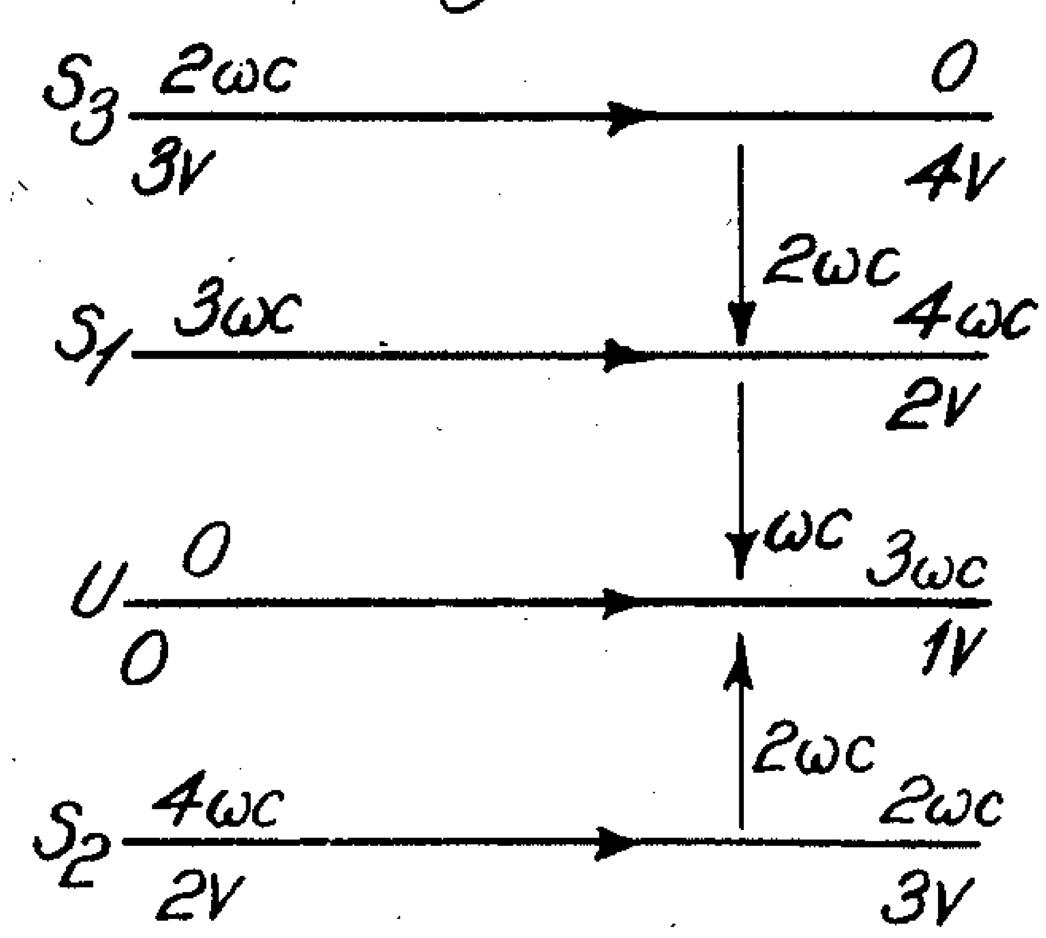


Fig. 15c.

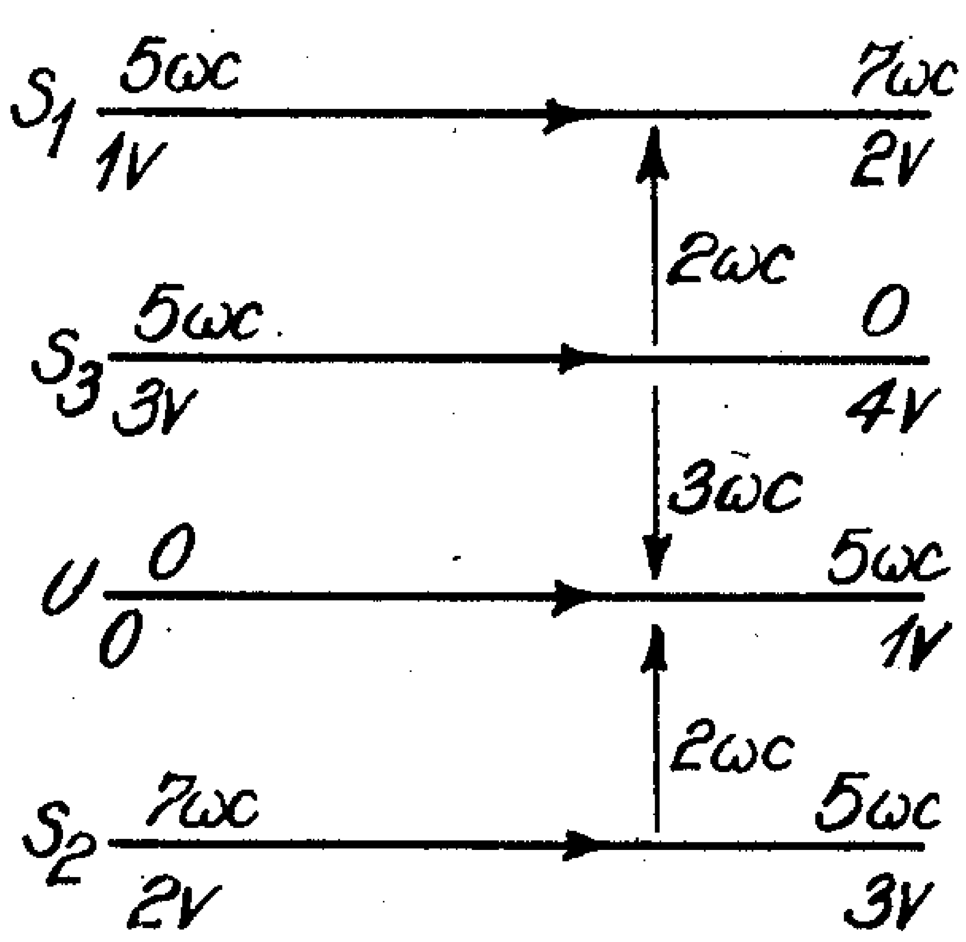
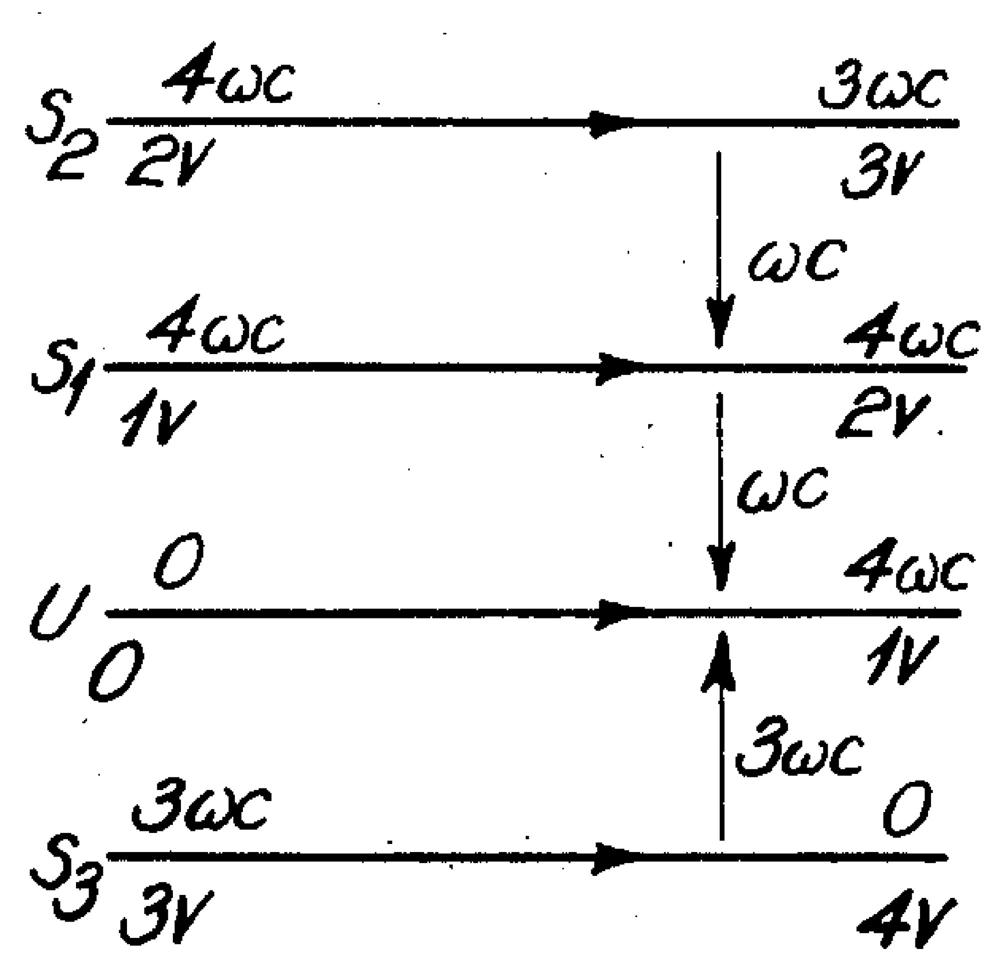


Fig. 15d.



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UNITED STATES PATENT OFFICE

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HIGH-FREQUENCY ALTERNATING CURRENT TRANSFORMER

Raymond Calvert, New Malden, England, assignor to The Wayne Kerr Laboratories Limited, Surrey, England, a British company

Application February 13, 1950, Serial No. 143,975

12 Claims. (Cl. 317—206)

This invention relates to alternating current transformers for use at high frequencies and particularly to transformers for use in alternating current bridge circuits of the kind in which two windings on a transformer form the ratio arms of the bridge.

High frequency transformers for alternating current bridges have heretofore been usually constructed with toroidal windings on a ring core, the core being of rectangular cross-section built up of a number of layers of high permeability tape. It is the usual practice for the primary winding to be wound toroidally on the core extending around the whole length of the core. Over this winding is fitted a copper screening ring which covers the entire core and primary winding but is slit along the length of its face around the inside of the ring to avoid forming a short circuited turn. The secondary windings, comprising one or more turns of copper tape spaced with insulation of one or two thousands of an inch thickness are arranged on the outside of the screening ring. The copper tape has to be wound on a flat surface whereas the ring is curved along its length and therefore, to form a suitable foundation on which to wind the tape, a former is built up to a rectangular or circular cross-section by winding on the screening ring a number of turns of suitable insulating material.

One of the main electrical disadvantages of this form of construction is that it causes a large amount of leakage inductance; this is partly due to the air spaces between the secondary winding and the screening ring through which leakage flux can flow and partly due to the unnecessarily large periphery of the secondary winding both of which features are consequent upon the necessity of building up a former on which to wind the flat copper tape. In the kind of bridge circuits mentioned above, leakage inductance is highly undesirable. It may be reduced, by various expedients, but even then is far from negligible at high radio frequencies. Furthermore, any form of construction which is adopted to keep down the leakage inductance tends to raise the winding capacity, so that the windings, in addition to their normal circuit currents, also carry appreciable capacity currents. These in turn set up leakage fluxes which, unless correctly proportioned, can lead to serious errors in measurements at high frequencies.

The object of the present invention is to provide a transformer for use at high frequencies in which (*a*) leakage inductance is reduced to a minimum, (*b*) the residual leakage inductance

can be distributed in any desired way between two or more windings, and (*c*) the voltage deviations between windings, due to the interaction of winding capacity on leakage inductance, can be brought under control.

These three requirements are achieved in the following order. First, the overall construction of the transformer is dealt with; it is made physically as small as possible, air spaces are eliminated, the peripheries of windings are reduced, and so forth, all with the object of bringing the leakage inductance to a minimum. Secondly, the required distribution of residual leakage inductance between windings is approximated by a suitable disposition of turns. Thirdly, without changing the relative positions of windings, permutation of the individual turns of the windings is made to establish the optimum ratio of reactive volts due to capacity currents.

Further features of the invention will be apparent from the following description of a number of embodiments thereof reference being made to the accompanying drawings in which:

Figure 1 is a front view of a high frequency transformer of the kind used heretofore, with part of the screening ring and secondary winding former cut away;

Figure 2 is a side view of the transformer of Figure 1 with the top half in section along the line 2—2 of Figure 1;

Figure 3 is a part view of a high frequency transformer constructed according to the present invention with part of the screening ring and secondary winding former cut away;

Figure 4 is a side view of the transformer of Figure 3 with the top half in section along the line 4—4 of Figure 3;

Figures 5 and 6 are views respectively similar to Figures 3 and 4 of a second embodiment of the invention;

Figure 7 is a diagrammatic section through the secondary winding of a transformer, the spacing between layers being exaggerated;

Figure 8 is a perspective view of another construction of transformer;

Figure 9 is a diagrammatic section through the windings of the transformer shown in Figure 8,

Figure 10 is a diagram illustrating the transformer windings;

Figure 11 is a diagrammatic illustration of the secondary windings cut and opened out flat;

Figures 12 (*a*), (*b*), (*c*) and (*d*) are diagrams illustrating the currents in the various turns of the secondary windings and the resultants M. M. F.'s,

Figure 13 illustrates the method of folding the tapes of the secondary windings; and

Figures 14(*a*) and (*b*) and Figures 15(*a*), (*b*), (*c*) and (*d*), are diagrams illustrating the capacity currents in the secondary windings.

In order to understand the present invention more clearly, it is necessary to refer to the types of transformer heretofore used. A typical transformer is shown in Figures 1 and 2 and comprises a ring core **10** on which toroidally is wound a primary winding **11** which extends around the whole of the core. Over the primary winding is a copper screening ring **12** which has a slit **13** extending around its inner surface to prevent the screening ring forming a short circuited turn. The secondary windings comprising one or more turns of copper tape **14** with insulating spacing are placed on the outside of a former **15** which is built up to a rectangular section by winding on the screening ring a number of turns of suitable insulating material. Three tapes **16**, **17**, **18** are lead out sideways from the winding providing connections to the two ends and to an intermediate point between the ends. As indicated above, the leakage inductance with this construction is relatively great due partly to the air spaces indicated by the reference **19** and partly to the large periphery of the secondary winding.

Figures 3 to 9 show transformers constructed according to the present invention in which the air spaces have been eliminated and the secondary winding periphery greatly reduced.

Referring to Figures 3 and 4, the core **20** is made D-shaped instead of circular. Regarding the copper screening ring as a coupling turn between the primary and secondary windings, it is clear that there is no necessity to place any part of the primary winding immediately underneath the secondary wingings. The primary winding **21** is wound on the curved part of the D-shaped core and the screening ring **22** is drawn in to become a close fit on the core along the straight part of the D. As is seen more closely from Figure 7 which is a diagrammatic section through the secondary winding with the spacing of the layers exaggerated, the secondary winding **23** formed of copper tape is then wound over this straight part on top of a layer of insulation **24**. This winding is formed of a number of successive layers separated by thin insulation and is arranged in a manner to be described hereinafter.

Figures 5 and 6 show a construction which is generally similar to that of Figures 3 and 4 and the same reference numerals have been used to indicate similar components. In this arrangement however, the screening ring **22** has been made a close fit on the core **20** except at one place where it is drawn out to accommodate the primary winding **21**.

Another construction is shown in Figures 8 and 9 in which a dust iron core is formed of two L-shaped members **25**. The secondary winding **26** is wound on top of the primary winding **27**. No intermediate screening is used and in order to preserve the capacity balance between the primary and secondary windings, an extra half turn **28** is disposed between the two windings, one end of this half turn being connected to the outer end of the primary winding **27**. Preferably in this arrangement the outer end of the primary winding is earthed. The arrangement shown in Figures 8 and 9 obviates the necessity for a screening ring and is particularly suitable for very high frequency bridges.

By these arrangements the air spaces under the secondary windings are eliminated and the periphery of this winding has been greatly reduced. Having thus brought the leakage inductance to a minimum, the next requirement is to control the distribution of the residual leakage between the windings.

For ease of description the particular example of the current transformer in a high frequency admittance bridge such as that described in my copending application Serial No. 143,976 filed February 13th, 1950, now Patent No. 2,589,535, and entitled "High Frequency Alternating Current Bridges" will be considered. The transformer is shown schematically in Figure 10 and comprises a first winding **30** (the primary winding) connected to a detector and two secondary windings, one of which referred to hereinafter as the standard winding comprises in this particular example three turns which will be called S1, S2 and S3 turns and connects the standard impedance to the neutral connection. The other secondary winding connects the unknown impedance to the neutral connection and is therefore referred to as the unknown winding and its single turn will be called the U turn. In the type of bridge referred to these two secondary windings form the ratio arms. Ideally the bridge should balance when the current through the unknown is three times the current through the standard, and in the balance condition the transformer terminals connecting the unknown and standard should both be brought to the potential of the neutral connection, owing to the cancellation of fluxes in the two windings. In practice, of course, there must be leakage flux in the windings so that when the core fluxes cancel, giving zero voltage on the detector winding, there will remain small reactive voltages at the standard and unknown terminals. These voltages will cause errors in measurement unless they are correctly proportioned so as to cancel in their effect.

Since the leakage inductances arise from the magnetic fluxes that flow in the spaces between turns, it is convenient for the calculation of leakage inductance to imagine the windings cut through and opened out flat. This is shown in Figure 11, which is greatly distorted to enable the dimensions to be marked. The dimension line l indicates the length of a single turn of the winding, W indicates the width of the tape forming the winding and d is the spacing between the successive layers.

As a particular example, it will be assumed that there is an instantaneous current of 1 amp. in the standard winding and 3 amps. in the unknown winding, in the sense shown in Figure 10. First, a calculation will be made of the leakage inductances when the single turn, U, of the unknown winding is the inner turn, and the three turns, S_1, S_2 and S_3, of the standard winding are placed on top of it. This state of affairs is represented in Figure 12(*a*), which shows a cross section of the cut and flattened windings of Figure 11 and is useful as an aid to calculation.

In the space (*a*) of Figure 12(*a*) there is a flux 3η units downwards through the plane of the paper caused by the current in turn U. There is also a flux in 1η units downwards through the plane of the paper due to each of the currents in turns S_1, S_2 and S_3. The result is as though the space (*a*) was acted upon by an M. M. F. of

3 ampere turns. In space (b) there is a flux of 3η units down through the plane of the paper due to the current in U, and fluxes of 1η units down through the plane of the paper due to the currents in S_2 and S_3; but a flux of 1η units up through the plane of the paper due to the current in turn S_1. The resultant is as though the space was acted upon by a M. M. F. of 2 ampere turns. Similarly the flux in the space (c) is as though it was acted upon by a M. M. F. of 1 ampere turn. These figures are marked in the spaces on the diagram. Knowing the M. M. F., it is possible to calculate the reluctance of the flux path. From Figure 10 it is clear that the reluctance of the portion of the flux path inside the winding is

$$\frac{W}{dl}$$

In view of the small dimension d—one or two mils only—it is clear that the reluctance of the flux path outside the winding is extremely small compared with the reluctance of the portion of the path inside and, therefore, to a first approximation it can be ignored. Knowing the M. M. F.'s and the reluctances of the flux paths, the fluxes in the spaces can be written down as follows:

$$\text{Flux in } (a)=\frac{4\pi 2.54 d.l}{10W}3=3.19\frac{dl}{W}3$$

$$\text{Flux in } (b)=3.19\frac{dl}{W}2$$

$$\text{Flux in } (c)=3.19\frac{dl}{W}1$$

(dimensions in inches)

The flux linkages for the turns are as follows:

$$\text{Flux linkages in turn } U=0$$

$$\text{Flux linkages in turn } S_1=3.19\frac{dl}{W}3$$

$$\text{Flux linkages in turn } S_2=3.19\frac{dl}{W}(3+2)=3.19\frac{dl}{W}5$$

$$\text{Flux linkages in turn } S_3=3.19\frac{dl}{W}(3+2+1)=3.19\frac{dl}{W}6$$

The effective leakage inductance of the U winding is clearly zero, since the single turn of this winding embraces no leakage flux. The effective leakage inductance of the S winding is found by dividing the total flux linkage for the three turns of the winding by the current. This gives:

$$\text{Leakage inductance of the } S \text{ winding}=L_s=3.19\frac{dl}{W}$$

or

$$L_s=0.0319\frac{dl}{W}14\mu\text{hy.}$$

With this particular arrangement of winding it is clear that the whole of the effective leakage inductance occurs in the S winding, and that if it is desired to distribute it in some proportion between the S and U windings, the U turn must be allowed to embrace some of the leakage flux. Suppose, therefore, that the winding be arranged as indicated in Figure 12(b). That is to say S_1 is made the inner turn, U the next turn and S_2 and S_3 the final two turns. The calculation is carried through as above. Defining positive flux as flux downwards through the plane of the paper, it is first of all necessary to reckon the effective M. M. F. acting on the spaces a, b, and c—these are marked in the figure—then the space fluxes and flux linkages per turn. Finally, the flux linkages are added, divided by the current and multiplied by 10^{-8}. The result is:

$$L_u=0.0319\frac{dl}{W}\frac{1}{3}\mu\text{ hy.}$$

$$L_s=0.0319\frac{dl}{W}3\mu\text{ hy.}$$

If the U turn is moved one more turn away from the core the arrangement is as shown in Figure 12(c), and if it is placed completely outside the S winding, as shown in Figure R(d). A calculation of the leakage inductances gives the following:

For Figure R(c)

$$L_u=0.0319\frac{ld}{W}1\mu\text{ hy.}$$

$$L_s=0.0319\frac{ld}{W}3\mu\text{ hy.}$$

and for Figure 9(d)

$$L_u=0.0319\frac{ld}{W}2\mu\text{ hy.}$$

$$L_s=0.0319\frac{ld}{W}4\mu\text{ hy.}$$

Leakage inductances have now been calculated for a turn by turn withdrawal of the U turn from the inside to the outside of the winding. It should be explained however that these particular positions for the U turn are chosen solely for simplicity of illustration. The withdrawal can equally well be continuous. The windings could, for instance, be arranged as follows:

1st layer $\frac{3}{4}S_1+\frac{1}{4}U$
2nd layer $\frac{3}{4}U+\frac{1}{4}S_1$
3rd layer S_2
4th layer S_3

That is to say, the U winding could be started ¾ turn from the core end. Indeed, there is no reason other than ease of physical construction why the U turn itself should be put on as a continuous strip. In short, the two windings can be broken into sections and the sections interleaved in any desired way to achieve a particular ratio of leakage inductances.

The necessary electrical continuity of the windings can be achieved either by bringing out interconnecting tapes at right angles to the direction of winding, or alternatively by cross-overs formed by folding the tapes as shown in Figure 13. In this figure there are shown two conducting tapes marked X and Y with a layer of insulation between them. By successively folding the tapes and insulation together in three folds as illustrated, the order of the layers may be reversed i. e. the lowest layer is brought to the top. It will be appreciated that by employing a succession of such cross-overs, any turn of the winding may be brought out through all the overlying turns.

In many applications it is desirable to be able to trim the leakage inductance ratio to allow for stray inductances in the external circuit. This is conveniently done as follows. The transformer is so designed that the leakage inductance of the winding that includes the outer turn is slightly below its estimated required value. The leakage inductance of this winding can then be increased as required by increasing the spacing between the final turn and the rest of the winding over a part, or the whole of the periphery, as is illustrated diagrammatically in Figure 7 the spacing **40** between the final turn and the rest of the winding is greater than the spacing **41** between the inner turns.

This same technique of increasing (or decreasing), the insulation thickness in the outer turns is sometimes useful in overcoming constructional difficulties associated with fractional turn interleaving. For example, with a square winding cross section it is difficult to bring out interconnecting tapes at places other than integral multiples of a quarter turn. In such cases, if the required result cannot be achieved by folding the tapes to give cross-overs, it is convenient to make the connections to the nearest quarter turn and then to achieve the required leakage inductance ratio by suitably varying the insulation thickness.

For ease of description the discussion has been confined to one particular type of transformer, but the same principles can be applied equally well by obvious extensions of the argument to many other types.

Having satisfied the first two requirements, it is now only necessary to be able to control the effects of leakage flux due to capacity currents. The discussion will again be confined to the particular example of the transformer described above.

First, the winding arrangement of Figure 12(*b*) should be considered, where the U turn is one turn removed from the core end of the winding. It should be assumed that the transformer is disconnected from the circuit on its U and S windings and excited on its detector winding so as to induce 1 volt per turn.

Let the instantaneous voltages be as indicated in Figure 14(*a*). The winding connections are as follows: The start of the U turn is an open circuit and at zero voltage; there is a rise of voltage along the U turn to 1 volt at the end, which is connected to the start of the S_1 turn; the finish of the S_1 turn, which is at 2 volts, is connected to the start of the S_2 turn; the finish of the S_2 turn, at 3 volts, is connected to the start of the S_3 turn; the finish of the S_3 turn, at 4 volts, is an open circuit.

Let the capacity between turns be C, which is given by the usual formula:

$$C=0.2244K.\frac{W.l}{d}\mu\mu\text{f}.$$

where K is the dielectric constant of the insulating material and the dimensions are in inches as indicated in Figure 11.

Between any point on the S_3 turn and a point immediately below it on the S_2 turn there is an instantaneous potential drop of 1 volt. Between any point on the S_2 turn and the point immediately below it on the U turn there is an instantaneous potential drop of 2 volts. Between any point on the U turn and the point immediately below it on the S_1 turn there is an instantaneous potential drop of minus 1 volt.

It is now necessary to consider a small element of length Δl of the cross section of the winding immediately to the left of the finish of the S_3 turn. The capacity between the S_3 and S_2 turns for this element of length is

$$\frac{\Delta l}{l}C$$

The voltage across it is 1 volt, therefore a capacity current

$$\Delta i=j\omega\frac{\Delta l}{l}C$$

must flow from the element of the S_3 turn to the element of the S_2 turn.

Since the finish of the S_3 turn is an open circuit no current can flow into the element from the right. It must therefore flow in from the left. Continuing along the S_3 turn to the left, every element of length Δl withdraws a capacity current of

$$j\omega\frac{\Delta l}{l}C$$

and every increment of capacity current must clearly flow from the left. Integrating along the turn shows that there is a linearly rising current in the tape to a maximum value of $j\omega c$ at the start. But the start of the S_3 turn is connected to the finish of the S_2 turn. The finish of the S_2 turn must therefore carry a current in its tape of $j\omega c$ flowing to the right. Proceeding back along the winding, that is to the left along S_2, it is clear that each element of length Δl receives a current of

$$j\omega\frac{\Delta l}{l}C$$

from the S_3 tape above it and gives out a current of

$$2j\omega\frac{\Delta l}{l}C$$

to the tape below it. Integrating along S_2 to the left there is consequently, a linearly rising current to a value of $2j\omega c$ at the start of the turn. The start of the turn is however connected to the finish of the S_1 turn, which must therefore also carry a current of $2j\omega c$ flowing to the right. Each element of the S_1 tape gives an increment of current to the U tape. Integrating along S_1 to the left shows a linearly rising current to a value of $3j\omega c$ at the start. Finally integrating along the U tape, it is easily shown that the current falls linearly from a value of $3j\omega c$ at the end to zero at the start.

The extreme value of currents are shown on Figure 14(*a*) with arrows indicating the direction of instantaneous current flow.

A calculation is now made of the leakage fluxes resulting from the capacity currents.

At a point x, where x is measured from the start of a turn, the conductor currents are:

$$\text{Current in } S_3=j\omega c\left(-\frac{x}{l}+1\right)$$

$$S_2=j\omega c\left(-\frac{x}{l}+2\right)$$

$$U=j\omega c3\frac{x}{l}$$

$$S=j\omega c\left(-\frac{x}{l}+3\right)$$

Defining positive flux as flux down through the plane of the paper, and remembering that flux below the bottom turn embraces all turns and can therefore be ignored as it gives rise to correctly proportional voltages on the two windings; the effective M. M. F.'s at x in the inter-turn spaces (*a*), (*b*), and (*c*) are as follows:

$$\text{M. M. F. at } x \text{ in space } (a)=j\omega c\frac{x}{l} \text{ amp. turns}$$

$$\text{M. M. F. at } x \text{ in space } (b)=-j\omega c\frac{2x}{l} \text{ amp. turns}$$

$$\text{M. M. F. at } x \text{ in space } (c)=-j\omega c\left(\frac{x}{l}+2\right) \text{ amp. turns}$$

The reluctance of the flux path over a length Δx is

$$\frac{W}{d\Delta x}$$

so the instantaneous fluxes can be written as follows:

Instantaneous flux at x in space (a)=

$$\frac{4\pi}{10}2.54\frac{d\Delta x}{W}j\omega c\frac{x}{l}=3.19j\omega c\frac{d}{W}\frac{x}{l}\Delta x$$

Instantaneous flux at x in space (b)=

$$-3.19j\omega c\frac{d}{W}\frac{2x}{l}\Delta x$$

Instantaneous flux at x in space (c)=

$$-3.19j\omega c\frac{d}{W}\left(\frac{x}{l}+2\right)\Delta x$$

(dimensions in inches)

The total instantaneous fluxes in the spaces (a), (b), and (c) are given by integrating through the range $0-l$. This gives:

$$\text{Total flux in } (a)=3.19j\omega c\frac{d}{Wl}\int^{l}xdx=3.19j\omega c\frac{dl}{W}\frac{1}{2}$$

$$\text{Total flux in } (b)=3.19j\omega c\frac{dl}{W}1$$

$$\text{Total flux in } (c)=3.19j\omega c\frac{dl}{W}2.5$$

The instantaneous flux linkages on the four conductors are therefore:

$$\text{On } S_3=-3.19j\omega c\frac{dl}{W}3$$

$$S_2=-3.19j\omega c\frac{dl}{W}0.5$$

$$U=+3.19j\omega c\frac{dl}{W}0.5$$

$$S_1=0$$

The total instantaneous flux linkages of the S winding are:

$$=-3.19j\omega c\frac{dl}{W}3.5$$

and on the U winding

$$=3.19j\omega c\frac{dl}{W}0.5$$

The reactive volts on the two windings due to capacity currents are therefore:

$$\text{On S winding}=3.19\omega^2C\frac{dl}{W}3.5\ 10^{-8}$$

$$\text{On U winding}=-3.19\omega^2C\frac{dl}{W}0.5\ 10^{-8}$$

Replacing C by its value of

$$0.2244K\frac{wl}{d}10^{-12}$$

the reactive volts on the two windings resulting from the leakage flux of the capacity currents are as follows:

Reactive volts on S winding=3.5N
Reactive volts on U winding=−0.5N
where $N=0.716Kw^2l^2 10^{-20}$

It will now be shown how the reactive volts on the winding due to capacity currents can be varied without altering the effective leakage inductance of the windings.

In the transformer under consideration, the U winding has a single turn and the S winding has three turns. In calculating the leakage inductances of the two windings, a current of 1 amp. was assumed in the S winding and 3 amps. in the U winding, and an estimate was made of the leakage fluxes in the spaces between turns. If the three turns S_1, S_2 and S_3 each carry 1 amp. of circuit current, it is clear that their positions can be interchanged without affecting the leakage inductances, provided only that the correct sense of winding is preserved. But interchanging their position will have a considerable effect on the capacity currents, as it will change the values of induced voltage between turns without changing the actual inter-turn capacity. This will be clear from Figures 15(*a*), 15(*b*), 15(*c*) and 15(*d*), which show four different arrangements of the turns S_1, S_2, S_3. In each case the turns are connected as follows: end of the U turn to start of S_1 turn; end of S_1 turn to start of S_2 turn; end of S_2 to start of S_3 turn; so that the leakage inductances are unaffected.

The reactive voltages resulting from the leakage flux of the capacity currents are calculated as above. They are:

For the arrangement of Figure 15(a)

Reactive volts on S winding=−3N
Reactive volts on U winding=−2N

For the arrangement of Figure 15(b)

Reactive volts on S winding=0.5N
Reactive volts on U winding=−1.5N

For the arrangement of Figure 15(c)

Reactive volts on S winding=−2.5N
Reactive volts on U winding=−2.5N

For the arrangement of Figure 15(d)

Reactive volts on S winding=−10N
Reactive volts on U winding=−4N

Another way of changing the distribution of leakage fluxes due to capacity currents in the inter-turn spaces, and hence of changing the ratio of reactive volts induced in the two windings by capacity current, is by the introduction of dummy turns, or fractional turns. This amounts to the introduction of a third winding, connected to a suitable point on the bridge winding at one end and open circuited at the other. This will have no effect on the leakage inductances of the S and U windings (since it causes no circuit currents) except insofar as it will change the effective inter-turn spacing if it is introduced in the middle of the windings; but it will carry a capacity current depending in amplitude and sense on its point of connection to the S and U winding and its place of introduction in the winding. The effect is calculated by an identical procedure to that described above. Such a dummy turn is arranged in a similar manner to the half turn 23 illustrated in Figure 9.

Although a number of specific embodiments of the invention have been described and shown herein, it will be understood that the details of construction shown may be altered without departing from the spirit of the invention as defined by the following claims.

I claim:

1. A high frequency alternating current transformer comprising a core member; a primary winding extending over one part of the core; a screening member of metal closely fitting over and substantially enclosing both the core member and primary winding and a pair of secondary windings wound outside the screening mem-

ber over a part of the core remote from the primary winding, one of the secondary windings comprising a number of successive layers of a conductor and the other secondary winding comprising at least one turn disposed between the layers of said one winding.

2. A high frequency alternating current transformer comprising a core member shaped to form a closed magnetic circuit and having a straight portion; a primary winding wound on part of the core remote from said straight portion; a screening member of metal substantially enclosing both the core member and the primary winding which screening member has a slit extending continuously along its length around the core and is arranged to fit closely over said straight portion of the core; and a pair of secondary windings formed of metal tape wound over the screening member on said straight portion, one of the secondary windings comprising a number of successive layers of tape and the other secondary winding comprising at least one turn disposed between the layers of said one winding.

3. A high frequency alternating current transformer comprising a core member shaped to form a closed magnetic circuit and having a straight portion; a primary winding wound on part of the core remote from said straight portion; and a pair of secondary windings formed of metal tape wound around the straight portion of the core, one of the secondary windings comprising a number of successive layers of tape and the other secondary winding comprising at least one turn disposed between the layers of said one winding.

4. A high frequency alternating current transformer comprising a core member shaped to form a closed magnetic circuit and having a straight portion; a primary winding wound on part of the core remote from said straight portion; a pair of secondary windings formed of metal tape wound around the straight portion of the core, one of the secondary windings comprising a number of superimposed layers of tape and the other secondary winding comprising at least one turn disposed between the layers of said one winding; and insulating material disposed between the successive layers of the secondary windings, the thickness of the insulating material between the final turn and the penultimate turn over at least a part of the periphery being greater than the thickness of the insulating material between the other layers.

5. A high frequency alternating current transformer comprising a core member shaped to form a closed magnetic circuit and having a straight portion; a primary winding wound on part of the core remote from said straight portion; a screening member of metal substantially enclosing both the core member and the primary winding which screening member has a slit extending continuously along its length around the core and is arranged to fit closely over the straight part of the core; a pair of secondary windings formed of metal tape wound over the screening member around the straight portion of said core, one of the secondary windings comprising a number of superimposed layers of tape and the other secondary winding comprising at least one turn disposed between the layers of said one winding; and insulating material disposed between the successive layers of the secondary windings, the thickness of the insulating material between the final turn and the penultimate turn over at least part of its periphery being greater than the thickness of the insulating material between the other layers.

6. A high frequency alternating current transformer comprising a core member, a primary winding extending over one part of the core, a pair of secondary windings wound over another part of the core remote from the primary winding, one of the secondary windings comprising a number of successive layers of a conductor and the other secondary winding comprising at least one turn disposed between the layers of said one winding, and insulating material disposed between the successive layers of the secondary windings, the thickness of the insulating material between the final turn and the penultimate turn over at least a part of the periphery being greater than the thickness of the insulating material between the other layers.

7. A high frequency alternating current transformer comprising a core member, a primary winding extending over one part of the core, and a pair of secondary windings wound over another part of the core remote from the primary winding, one of the secondary windings comprising a number of successive layers of a conductor the successive turns being connected in series in an order differing from the order in which they are wound on the core to minimize the effect of the winding capacity on the leakage inductance and the other secondary winding comprising at least one turn disposed between layers of said one winding.

8. A high frequency alternating current transformer comprising a core member shaped to form a closed magnetic circuit and having a straight portion, a primary winding wound on part of the core remote from said straight portion, and a pair of secondary windings formed of metal tape wound around the straight portion of the core, one of the secondary windings comprising a number of successive layers of tape the successive turns being connected in series in an order differing from the order in which they are wound on the core to minimize the effect of the winding capacity on the leakage inductance and the other secondary winding comprising at least one turn disposed between the layers of said one winding.

9. A high frequency alternating current transformer comprising a core member shaped to form a closed magnetic circuit and having a straight portion; a primary winding wound on part of the core remote from said straight portion; a screening member of metal substantially enclosing both the core member and the primary winding which screening member has a slit extending continuously along its length around the core and is arranged to fit closely over said straight portion of the core; and a pair of secondary windings formed of metal tape wound over the screening member on said straight portion, one of the secondary windings comprising a number of successive layers of tape the successive turns being connected in series in an order differing from the order in which they are wound on the core to minimize the effect of the winding capacity on the leakage inductance and the other secondary winding comprising at least one turn disposed between the layers of said one winding.

10. A high frequency alternating current transformer comprising a core member, a primary winding extending over one part of the core, a pair of secondary windings wound over the primary winding, one of the secondary windings comprising a number of successive layers of a

conductor and the other secondary winding comprising at least one turn disposed between the layers of said one winding, and a fourth winding connected at one end to a point on the primary winding and open circuit at the other end, which fourth winding extends over at least a fraction of a turn and is disposed between the primary and the secondary windings.

11. A high frequency alternating current transformer comprising a core member and a plurality of windings including a first winding having a number of successive layers of a conductor, a second winding disposed between the layers of said one winding and a compensating winding connected at one end to a point on one of the other windings and open circuit at the other end, to minimize the effect of the winding capacity on the leakage inductance, which compensating winding is disposed between the layers of the other windings.

12. A high frequency alternating current transformer comprising a core member, a primary winding of conducting tape wound on said core, a pair of secondary windings of conducting tape wound over the primary winding, one of the secondary windings comprising a number of successive layers of tape and the other secondary winding comprising at least one turn disposed between the layers of said one winding, and a fourth winding extending over at least a fraction of a turn between the primary and secondary windings with one end connected to the primary winding and the other end open circuit.

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