

[54] FLYBACK TRANSFORMER

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[56]

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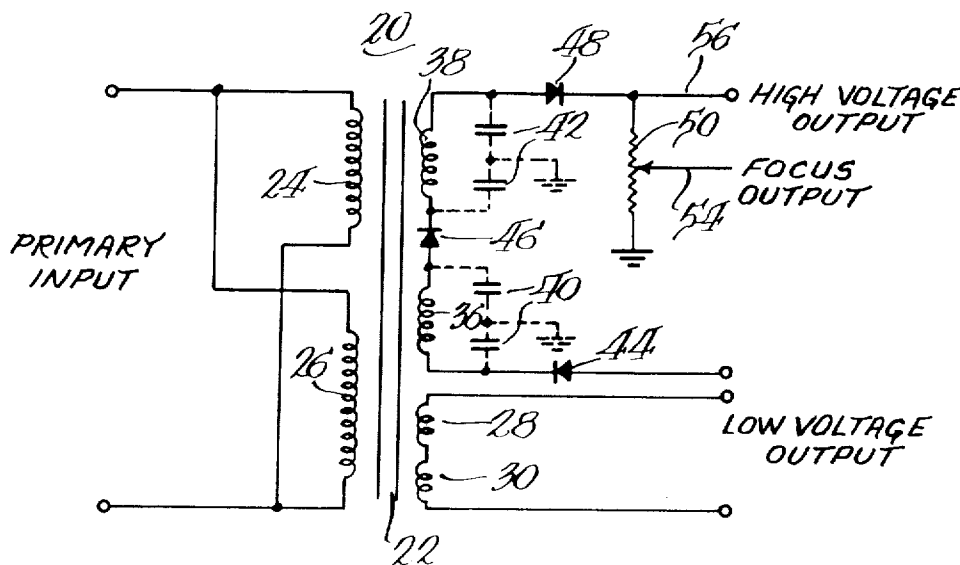
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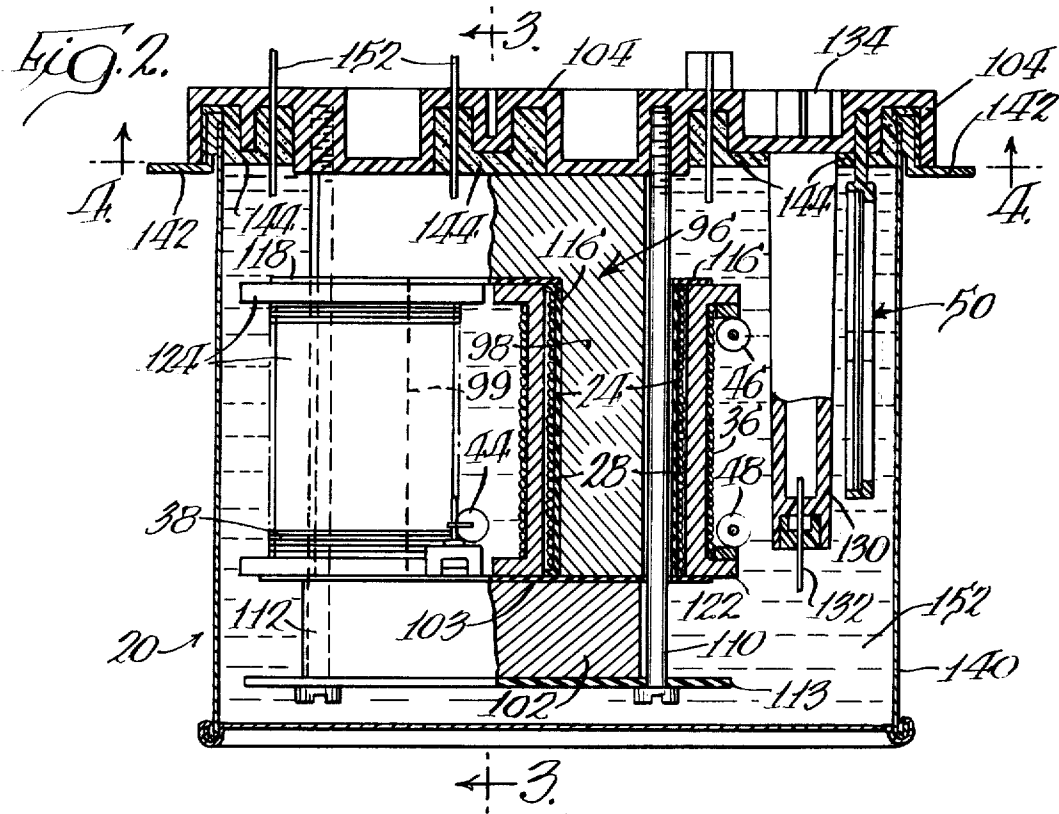
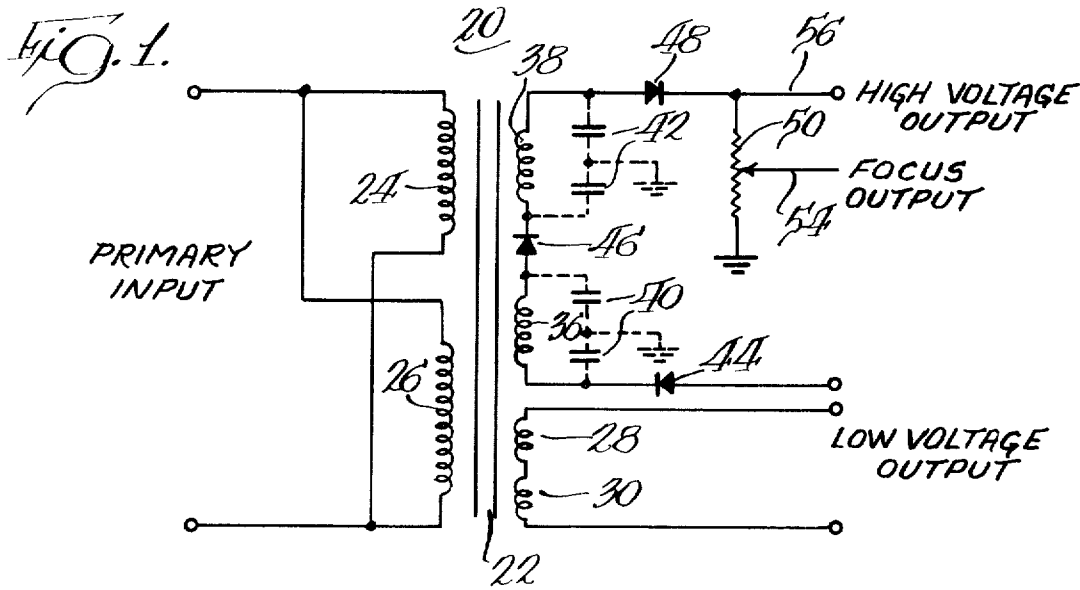
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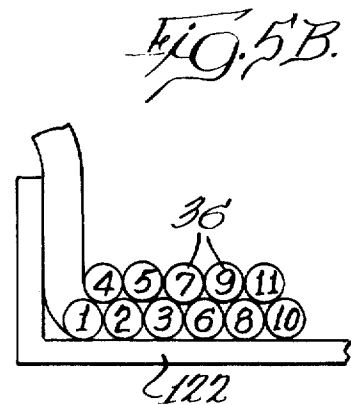
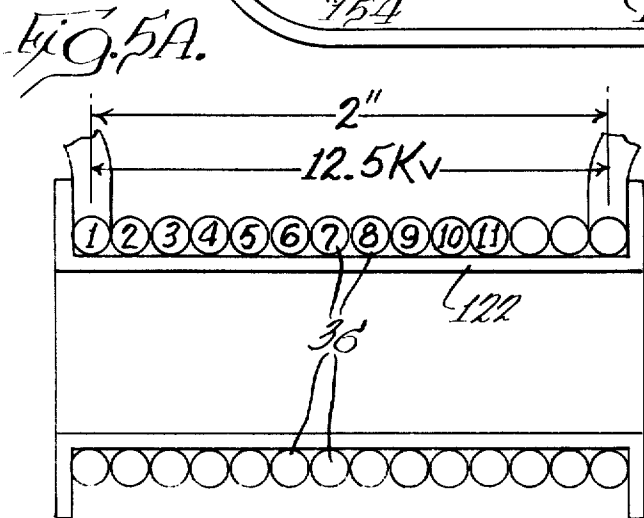
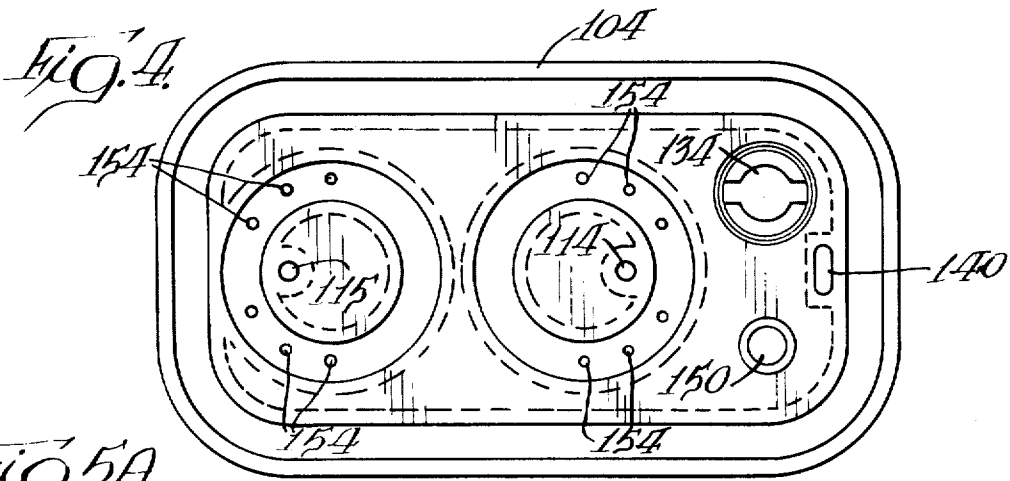
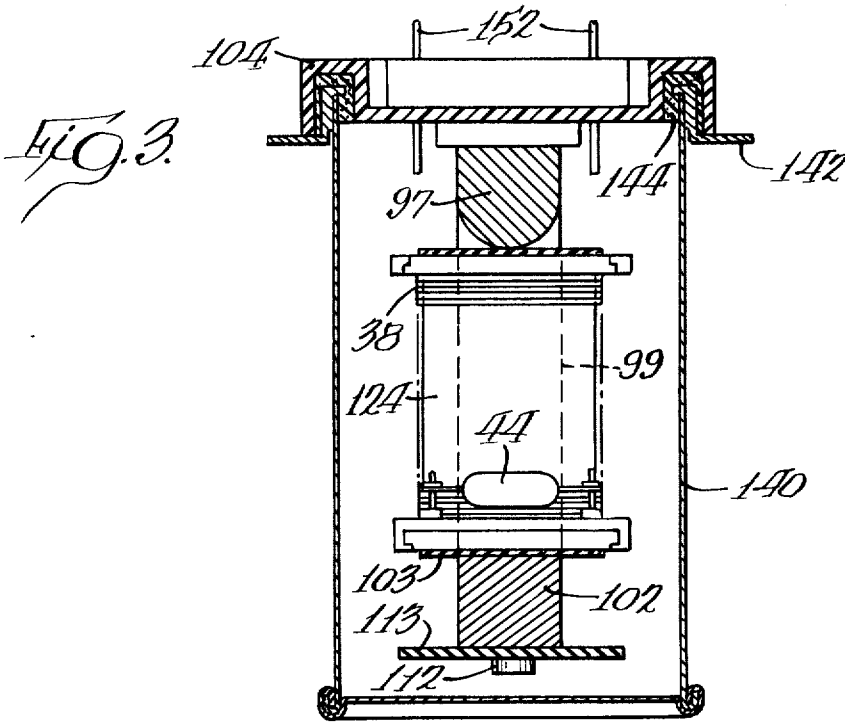
ABSTRACT

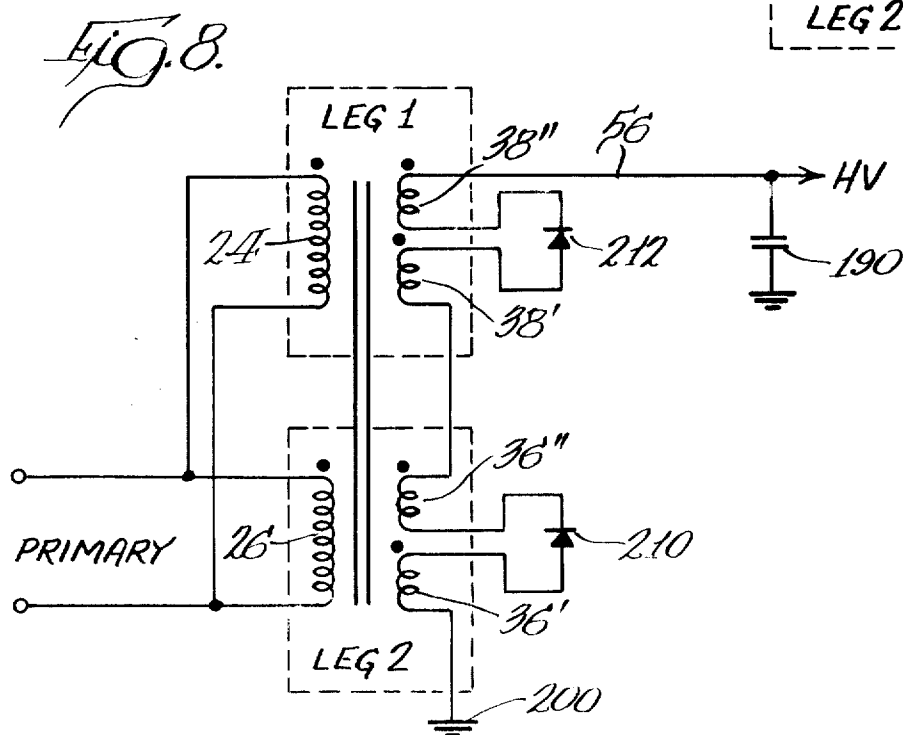
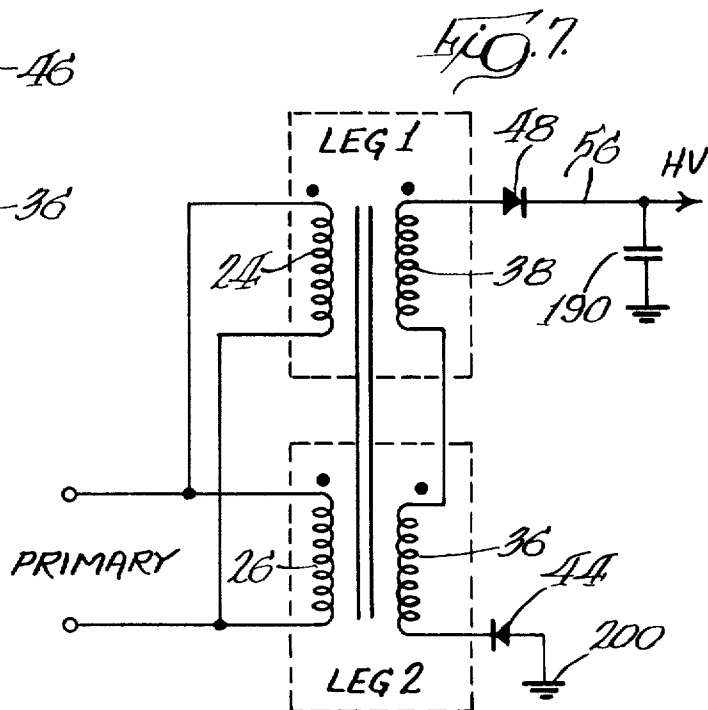
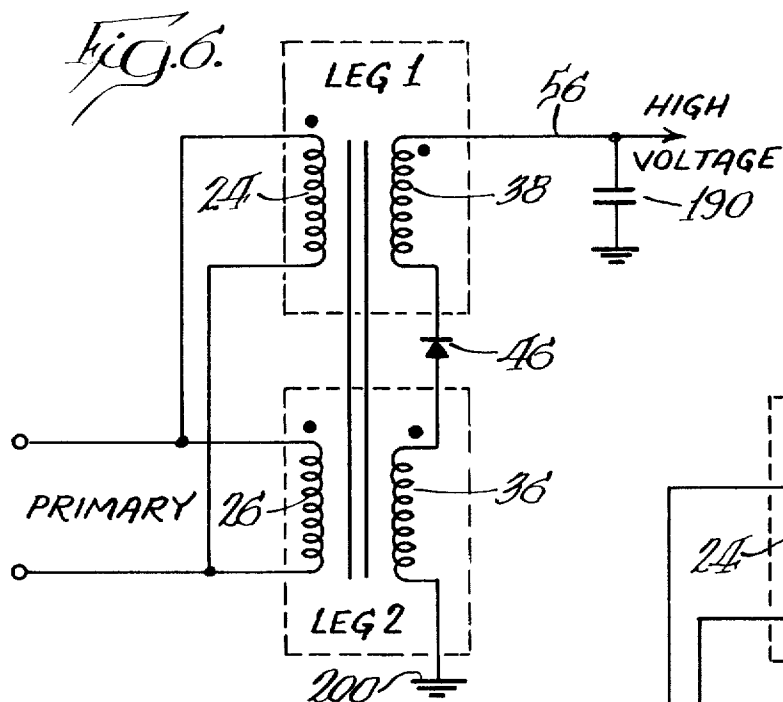
A high voltage horizontal flyback transformer assembly includes a generally rectangular ferromagnetic core with a pair of opposing core legs. A primary or low voltage winding is split into two portions each mounted on a different core leg with the winding distributed so as to cover as much of the core as possible. A high voltage winding is split into two or more portions, each placed as close to the core as possible and each wound in such a fashion as to cover as much of the core as possible, to thus increase mutual coupling. In particular, one half of the total high voltage winding is concentrically mounted over each of the low voltage portions. One or more diodes are located in series between the high voltage portions to reduce the effect of the high secondary distributed capacitance on the primary circuit, equalize the ringing frequencies of each high voltage section, and provide high voltage rectification. The entire transformer assembly, including the diodes and a focus resistor, is mounted in an oil-filled container.

6 Claims, 9 Drawing Figures









FLYBACK TRANSFORMER

BACKGROUND OF THE INVENTION

This invention relates to a horizontal flyback transformer for a television receiver, and more particularly to a flyback transformer with windings designed to increase primary to secondary coupling by having the windings encompass as much of the core as possible.

The horizontal flyback transformer in a television receiver generally includes a rectangular ferromagnetic core which carries a primary winding, a low voltage winding, and a high voltage winding.

To keep the voltage per layer to a safe value and to produce enough physical space between the start and finish of the high voltage winding in order to prevent voltage breakdown, prior flyback transformers have used a tall, narrow high voltage secondary winding. In early television receivers, this was a universal winding. With such a physical configuration in which the high voltage winding covers only a portion of the core, the mutual coupling is very low. With low mutual coupling, the transient ringing of the secondary cannot be controlled by primary damping coupled to the secondary. To minimize the damage produced by ringing, the ringing frequency has been controlled by tuning the high voltage winding to the third or fifth harmonic of the retraced frequency.

Flyback transformers using a tall, narrow high voltage secondary winding which encompasses a small portion of the core were developed to overcome problems encountered with early flyback transformers. It has been known to split the secondary and primary windings, and concentrically mount each on opposed legs of a single window core, as shown for example in U.S. Pat. Nos. 1,899,720 and 3,241,051. Unfortunately, such windings did not solve the transient ringing problem. The secondary/primary ratio is very high in flyback transformers, and since the secondary capacity is reflected into the primary winding as the square of the turns ratio, the resulting reflected capacity in the primary winding can prevent proper operation of the horizontal deflection circuit.

Thus, the stacked high voltage secondary of tall, narrow configuration has evolved in order to provide low mutual coupling and to maintain the voltage per layer to a safe value.

To reduce the effects of the leakage capacitance, a high voltage winding has been segmented and isolated by diodes as shown in U.S. Pat. No. 3,562,623. The entire transformer assembly including the diodes may be immersed in an oil-filled container, as shown in U.S. Pat. No. 3,657,632. Unfortunately, present configurations using a narrow high voltage secondaries have a number of disadvantages. The high voltage is not a direct function of the primary/secondary turns ratio, as in a low frequency transformer. Also, the transformer must be tuned, and the secondary ringing frequency is controlled by adjusting the winding configuration and/or by adding external tuning devices. Such transformers lend themselves to only an approximate mathematical solution, and much time must be spent in cut and try techniques to arrive at a desired result. The tuning of the secondary is quite difficult to hold in production and can vary with temperature and load changes. When mistuning occurs, transformer performance suffers and high voltage regulation may suffer along with overheating.

SUMMARY OF THE INVENTION

In accordance with the present invention, a horizontal flyback transformer is disclosed which has greatly increased mutual coupling between the primary/secondary windings, and further has low reflected primary capacity. The primary/secondary mutual coupling is increased by making all windings cover as much of the core as practical, and by placing the windings as close to the core as practical. In a specific embodiment, both legs of a single window core carry a split primary winding, which is spread along the length of the core, and a split secondary winding spread along substantially the same length. A winding technique for the secondary winding is utilized which will prevent voltage breakdown between the start and finish of the secondary, such as a progressive universal method or a random progressive method. To reduce the deleterious effects of stray capacitance and to equalize the ringing frequencies of all high voltage coil segments, one or more diodes are inserted between individual coil segments.

This technique reduces the effective turns ratio and the secondary capacity reflected to the primary winding. It also raises the natural resonant frequency of the secondary winding, and reduces the amplitude of any resultant ringing at the resonant frequency. Transformer efficiency and therefore high voltage regulation are improved by reducing the amount of energy otherwise dissipated in unwanted ringing. The result is a high voltage transformer that requires no critical tuning elements and behaves essentially as an untuned system.

One object of the present invention is the provision of a flyback transformer having greatly increased primary/secondary mutual coupling while still maintaining a low reflected secondary winding distributed capacity.

Another object of the present invention is the provision of a flyback transformer of improved and more reliable performance, of lower cost than prior flyback transformers, and which lends itself to mathematical design in order to reduce the number of steps necessary to design and produce an efficient transformer.

Other features and advantages of the invention will be apparent from the following description, and from the drawings. While illustrative embodiments of the invention will be described herein, the invention is susceptible of embodiment in several different forms and the present disclosure should be considered as an exemplification of the principles of the invention and is not intended to limit the invention to the illustrated embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a novel horizontal flyback transformer having increased primary/secondary coupling and low reflected distributed capacity;

FIG. 2 is a plan view, partly in section, illustrating the mechanical construction of the flyback transformer shown in FIG. 1;

FIG. 3 is a sectional view taken along lines 3—3 of FIG. 2;

FIG. 4 is a plan view of solely the top circuit board, looking along lines 4—4 of FIG. 2;

FIGS. 5A and 5B are diagrammatic illustrations of winding methods which may be used for the secondary winding;

FIG. 6 is a schematic diagram of another embodiment of the novel horizontal flyback transformer.

FIG. 7 is a schematic diagram of a modification to the transformer of FIG. 6, and

FIG. 8 is a schematic diagram of still another embodiment of a novel horizontal flyback transformer.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning to FIG. 1, a horizontal flyback or deflection transformer 20 for a television receiver includes a core 22 of ferromagnetic or other magnetizable material and a primary input winding divided into a first primary portion or coil 24 and a second primary portion or coil 26 which is electrically in parallel therewith. The secondary windings of the transformer include a low voltage winding which is split into two portions, consisting of a first low voltage coil 28 and a second low voltage coil 30 in series therewith. Other low voltage windings may be added as required.

Transformer 20 includes a high voltage winding split into two portions, consisting of a first high voltage coil 36 and a second high voltage coil 38. The stray capacitance 40 from coil segment 36 to ground, and the stray capacitance 42 from coil segment 38 to ground are represented by dashed lines. A plurality of semiconductor diodes 44, 46 and 48 are located in series with the coils 36 and 38.

The high voltage output, which illustratively may be on the order of 25 kilovolts, may be tapped to provide a focus voltage of 4 to 5 kilovolts. For this purpose, a tapped focus resistor 50 is connected to the high voltage output. The opposite end of resistor 50 may be connected to an external focus adjust potentiometer (not shown). A tap on resistor 50 is connected to a focus output line 54. A line 56 connected to the cathode of diode 48 serves as the high voltage output lead. A high voltage filter capacitor (not illustrated in FIG. 1) is formed by the capacitance of the picture tube dag which is coupled to line 56.

High voltage coils 36 and 38 cover as much of the core length as is practical, and are placed as close to the core as practical, as will be explained in detail later. The high voltage coils cover substantially all of the split primary coils to obtain a maximum value of mutual coupling, a winding technique for the high voltage coils is used which prevents voltage breakdown between the start and finish of the winding, and reduces insulation requirements.

To reduce the deleterious effect of the substantial amount of stray capacitance 40 and 42 produced by the type of winding necessary to increase inductive coupling, diode 46 is located between the individual coil sections 36 and 38, and diodes 44 and 48 are located at the outer end terminations of the high voltage winding. This produces a virtual ground at the winding center during the diode off time, reducing the effective turns ratio and hence the capacity reflected to the primary winding 24, 26. This also raises the natural resonant frequency of the high voltage secondary, with an ensuing reduction in the amplitude of any resultant ringing at the resonant frequency. Since all high voltage coil segments are symmetrical, all will ring at the same frequency. The transformer efficiency and high voltage regulation is improved by reducing the amount of energy otherwise produced in unwanted ringing.

In FIGS. 2-4, the mechanical construction is illustrated for the transformer 20. The ferromagnetic or magnetizable core 22 consists of a generally U-shaped core 96 having a center section 97 with a partially arcuate cross section, as seen in FIG. 3, and a pair of opposite side legs 98 and 99. A generally rectangular core segment 102 is located in close proximity to the pair of core legs 98 and 99, to complete a single window magnetic circuit. An insulating spacer 103 separates the core leg ends from the opposing surfaces of core segment 102, creating a pair of gaps in the single window magnetic circuit.

The flat bottom portion of the core center section 97 abuts a top terminal board 104, seen in detail in FIG. 4, which contains a plurality of extending terminals for external circuit connection. A pair of elongated screws 110 and 112 serve to clamp the core segments 96, 102 tightly between a bottom terminal board 113 and the top terminal board 104. The core side legs 98 and 99, respectively, contain concave indents located therein so as to provide elongated guide channels for the pair of screws 110 and 112 which screw into threaded apertures 114, and 115 in top terminal board 104.

The split low voltages coils 24 and 26 respectively wound on bobbins 116 and 118 which in turn are respectively mounted on the two core side legs 98 and 99. The low voltage coil 28 is also wound concentrically around bobbin 116. Similarly, low voltage coil 30 is concentrically wound about bobbin 118.

The split high voltage coils 36 and 38 are respectively located on core side legs 98 and 99 and in tight coupling with the coils on bobbin 116 and 118, respectively. The side core leg 98 includes a high voltage bobbin 122 which concentrically surrounds the low voltage bobbin 116. In a corresponding manner, the side core leg 99 carries a high voltage bobbin 124 which concentrically surrounds the low voltage bobbin 118.

Increased primary/secondary mutual coupling is accomplished by making all windings cover as much of the core length as practical, and by placing the windings as close to the core as practical. It would be desirable to have the windings cover even the end segments 97 and 102 of the core 22, but generally this is impractical from a manufacturing standpoint. Therefore, a compromise is made by filling each core leg 98 and 99 as much as possible, and by spreading the relatively few turns of the primary winding segments 24 and 26 over substantially the entire length of the core legs 98 and 99. Similarly, the high voltage secondary segments 36 and 38, which contain a substantial number of turns, are bunched over substantially the same length as covered by the primary winding. Thus, the high voltage secondary winding covers substantially all of the primary windings, contrary to prior art techniques in which a tall, narrow high voltage secondary winding covers only a small portion of the core leg and of the primary winding.

In order to prevent voltage breakdown between the start and finish of the high voltage secondary winding, several secondary winding techniques may be utilized. The secondary winding can be placed as close to the core as possible by utilizing a single-layer solenoid winding, as illustrated in FIG. 5A, which is concentric with the primary winding. Since two secondary segments are utilized and have a total of 25 kilovolts thereacross about 12.5 kilovolts appears across the length of the single segment carried by bobbin 122, which may

be two inches in length. The first lead on turn 1 is located at one end of the bobbin 122 and the terminating lead is located to the opposite end of the bobbin. In the prior art, the entire 25 kilovolts would appear across the narrow stack winding, which might have less than one inch extent. A single winding layer is possible by using a wire fine enough to allow all necessary turns to be completed within the fixed bobbin length, or by increasing the length of the core legs so that the necessary turns of wire can be accommodated.

The use of a wire fine enough to allow the necessary turns to be laid down in one layer may require a wire size too fine to be handled economically in production, and it may not be desirable to extend the length of the core legs. In such a situation, the required number of turns will not fit the bobbin in one layer, and multiple layers must be accommodated. The random progressive winding method, as shown in FIG. 5B, may then be utilized. The numbers 1, 2, 3, etc., in FIG. 5B indicate the number of the turn. It can be seen that the turns are laid down in a random manner, but progressing at a uniform rate from one end of the bobbin to the other. An alternate winding may be utilized which is a progressive universal winding, per se well known, which is similar to the random progressive winding of FIG. 5B, but the position of each turn is determined precisely and the pattern is repeated rigidly throughout the length of the bobbin. Either progressive winding causes the full bobbin length to occur between the starting lead and the finishing lead of the winding. Any of these three windings, namely (1) a single layer solenoid, (2) a random progressive winding, or (3) a progressive universal winding, produce a high voltage coil that needs no additional layers of insulation other than the winding insulation. Other winding methods may be used to practice the invention and will be apparent to those skilled in the art. The construction of a transformer incorporating the invention is not to be limited to the above three winding methods as these are used for purposes of illustration only.

Returning to FIGS. 2-4, a high voltage lead well 130 has a hollow cylindrical interior and a terminal 132 is brought out of well 130 through a hermetic seal. The high voltage lead 56 of FIG. 1 may be attached to terminal 132 and extend through the hollow interior of the well 130 and out an opening 134 for external connection to a television cathode ray tube.

The focus resistive divider 50 may be formed by a thick film resistor deposited on a base which attaches through a slot opening 140, see FIG. 4, to the top terminal board 104.

In order to prevent corona problems in the high voltage coils, particularly under high humidity or high altitude conditions, the entire transformer assembly including the diodes and focus resistor is hermetically sealed in an oil-filled container such as a metal can 140. The can 140 and a metal rim 142 are sealed to the top terminal board 104 by epoxy 144 which also serves to anchor a plurality of lug terminals 152 which extend through a plurality of spaced apertures 154 in the top terminal board 104. The top terminal board 104, see FIG. 4, includes an oil-fill hole 150 for filling the interior of the metal can 140 with an insulating oil 152. The insulating oil 152 allows for close spacing of components, and therefore a very compact flyback transformer assembly. Furthermore, the insulating oil serves as a cooling medium.

As previously explained, a winding with maximum inductive coupling has a very high distributed capacity. In the case of a high voltage flyback transformer, the secondary/primary ratio is very high, and hence the reflected capacity can prevent proper operation of the circuit. The effects of this distributed capacity can be reduced by proper placement of one or more high voltage rectifier diodes, such as the diodes 44, 46, 48 as shown in FIGS. 1 and 2. The operation of these diodes to reduce distributed capacity will now be explained with reference to several additional embodiments shown in FIGS. 6-8. Similar components have been identified with the same reference numerals as used in FIGS. 1-4. The coils are wound on bobbins surrounding and covering the entire length of the pair of opposite side legs 98 and 99 of FIGS. 2-4, as indicated by dashed lines labeled Leg 1 and Leg 2. The low voltage winding has been deleted, but one or more low voltage windings may include it as desired.

In FIG. 6, a single diode 46 is located in series between the first and second high voltage coils 36 and 38. The high voltage output (HV) of 25 kilovolts is available on line 56 which is coupled directly between the outer end of coil 38 and a high voltage filter capacitor 190, typically formed by the picture tube dag coating. Unlike many prior art flyback transformers, in which a high voltage rectifier is located at the high potential end of the secondary winding, the high voltage rectifier diode 46 is located between the two halves of the secondary winding. It will now be shown that the reflected distributed capacity produced by a segmented high voltage winding with series diode(s) is substantially less than produced by a secondary winding having a single high voltage rectifier located at the high potential end of the secondary winding.

First, a conventional configuration will be analyzed in which the rectifier diode is in series with line 56. It will be assumed that the secondary winding is of the tightly coupled, high distributed capacity type and that the transformer has a 200 turn primary winding and a total 2000 turn secondary winding and that the secondary coil has one capacitive unit per turn, so that the 2000 turn secondary winding would have a distributive capacity of 2000 units. Because during the trace period the rectifier diode is open circuited, the secondary looks like a coil with its high end open and its low end grounded. The grounded end cannot contribute to the distributed capacity so the assumed effective distributive capacity will be half of the 2000 units as indicated by 1000 turns at one unit per turn or 1000 units. The coupling factor is proportional to the square of the turns ratio, which is $(2000/200)^2$ or 100. Thus, their reflected capacity equals 100×1000 units or 100,000 units.

Referring now to the FIG. 6 circuit, the rectifier diode 46 when open circuited causes each half of the secondary winding to look like a coil with one end open and the other end grounded (the high side of the secondary winding is grounded through the filter capacitor 190). The total distributed capacity of each half of the secondary winding at one unit per turn equals 1000 units. Because the grounded end of each winding does not contribute any capacity, the average capacity of each half of the secondary winding is 500 units. Each half of the secondary acts independently in its coupling to the primary winding, so the coupling factor of each half of the secondary is $(1000/200)^2$ or 25. Reflected

capacity for each half of the secondary equals 25×500 units or 12,500 units. For both halves of the secondary winding, the total reflected capacity is double this figure or 25,000 units. It will be apparent that the reflected capacity has been reduced to one quarter by placing the rectifier diode between the pair of winding segments, rather than in series with the high voltage end of the winding.

In FIG. 7, the single rectifier diode is replaced by a pair of diodes **44** and **48**. These diodes cause both ends of each half of the secondary to be open circuited, forming balanced windings with a virtual ground in the center. When FIG. 6 and 7 are combined to produce the circuit shown in FIG. 1, a pair of balanced windings are produced which have a virtual ground at the center of each winding and thus each half of the secondary winding appears to be two 500 turn windings grounded at one end and open at the other. The 500 turn winding would have a distributed capacity of 500 units, but being grounded at one end, the average distributed capacity of each section would be 250 units. Each of the four sections couple back to the primary independently, so the coupling factor for each segment of the secondary sections is $(500/200)^2$ or 6.25. The reflected capacity of each segment of the secondary is thus $6.25 \times 250 = 1,562$ units. Since there are four segments, the total capacity reflected to the primary is 4 times this value or 6,258 units. Thus, the reflected primary capacity of a transformer of FIG. 1 is about one-sixteenth of the capacity of the typical prior art system in which a single rectifier diode is located in series with line **56**.

The above figures are only approximate as other factors enter into the calculations. The diodes conduct only during the retrace period, and thus look like an open circuit during the trace period which is the period where high primary capacity is detrimental. Other variations are also possible, as shown for example in FIG. 8, in which the high voltage winding is split into plural segments.

The first high voltage coil is split into a pair of segments **36'** and **36''**, with a diode **210** being located in series therebetween. Similarly, the high voltage coil on Leg 1 is split into a pair of segments **38'** and **38''**, and a diode **212** is located in series therebetween. The circuit of FIG. 8 has as low a reflected capacity as the circuit shown in FIG. 1, but uses one less diode. Other modifications will be apparent to those skilled in the art.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A transformer assembly for generating deflection voltage waveforms in a television receiver, said wave-

forms being inherently subject to harmonic oscillations caused by distributed capacitance in said transformer, said transformer comprising:

a U-shaped ferromagnetic core having an intermediate section and first and second generally parallel outer legs, a generally rectangular ferromagnetic core segment bridging said outer legs to complete a single window magnetic circuit;

a primary winding having first and second segments; a split high voltage winding having first and second segments;

a pair of low voltage bobbins carrying said primary segments surrounding and extending along and immediately adjacent to said first and second core legs respectively for substantially the entire length of said window and a pair of high voltage bobbins carrying said first and second high voltage segments respectively and surrounding said low voltage bobbins for substantially the entire length of said window;

voltage rectifier means connected in series with said high voltage winding segments and intermediate the terminating ends of said high voltage winding.

2. The transformer assembly of claim 1 including a low voltage winding concentric with said core for providing a low voltage output.

3. The transformer assembly of claim 1 wherein said high voltage winding comprises a single layer solenoid wound concentric with said primary winding and having a first lead located substantially at one end of said primary winding and a terminating lead located substantially at the opposite end of said primary winding.

4. A transformer assembly of claim 1 wherein the high voltage winding is wound concentric with said primary winding and in random progressive or progressive universal configuration and has an input lead substantially adjacent one end of said primary winding and a terminating lead located substantially adjacent the opposite end of said primary winding.

5. The transformer assembly of claim 1 wherein the voltage rectifier means includes a first voltage rectifier connected intermediate of a pair of terminating ends of said high voltage winding to reduce the distributed capacitance produced by the first and second high voltage segments.

6. The transformer assembly of claim 1 wherein said voltage rectifier means includes a second voltage rectifier, said first voltage rectifier being located in series with said first high voltage segment and intermediate the ends thereof and said second voltage rectifier being located in series with said second high voltage segment and intermediate the ends thereof.

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