United States Patent [19]

McLeod, Jr.

[11] **3,824,427**

[45] **July 16, 1974**

[54] **HIGH VOLTAGE REGULATOR**

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[73] Assignee: **Warwick Electronics Inc.**, Chicago, Ill.

[22] Filed: **Mar. 16, 1973**

[21] Appl. No.: **342,313**

[52] **U.S. Cl.** **315/29**

[51] **Int. Cl.** **H01j 29/70**

[58] **Field of Search** ..... 315/28–29, 315/27 SR, 27 TD, 23, 24, 27 R

[56] **References Cited**

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Primary Examiner—T. H. Tubbesing
Assistant Examiner—J. M. Potenza
Attorney, Agent, or Firm—Hofgren, Wegner, Allen, Stellman & McCord

[57] **ABSTRACT**

A horizontal flyback transformer in a television receiver includes a driving choke winding coupled to a horizontal drive stage. A regulating winding is wound on the same core leg as the driving choke winding. A high voltage winding and a primary winding for driving a horizontal deflection yoke coil are wound on an opposite core leg. To regulate the high voltage developed by the high voltage winding, the regulating winding is coupled to a variable loading circuit controlled by current through a resistor in series with the driving choke winding. Each core leg includes an air gap selected to cause the leakage inductance between the primary winding and the driving choke winding to be equal to the inductance of the primary winding.

21 Claims, 10 Drawing Figures

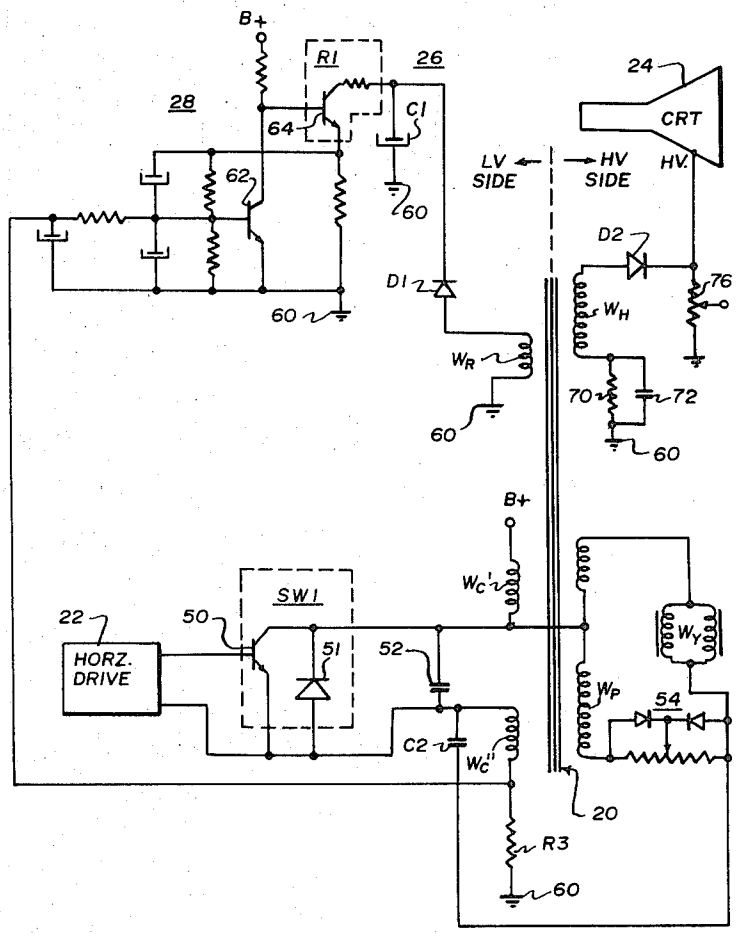


FIG. 1

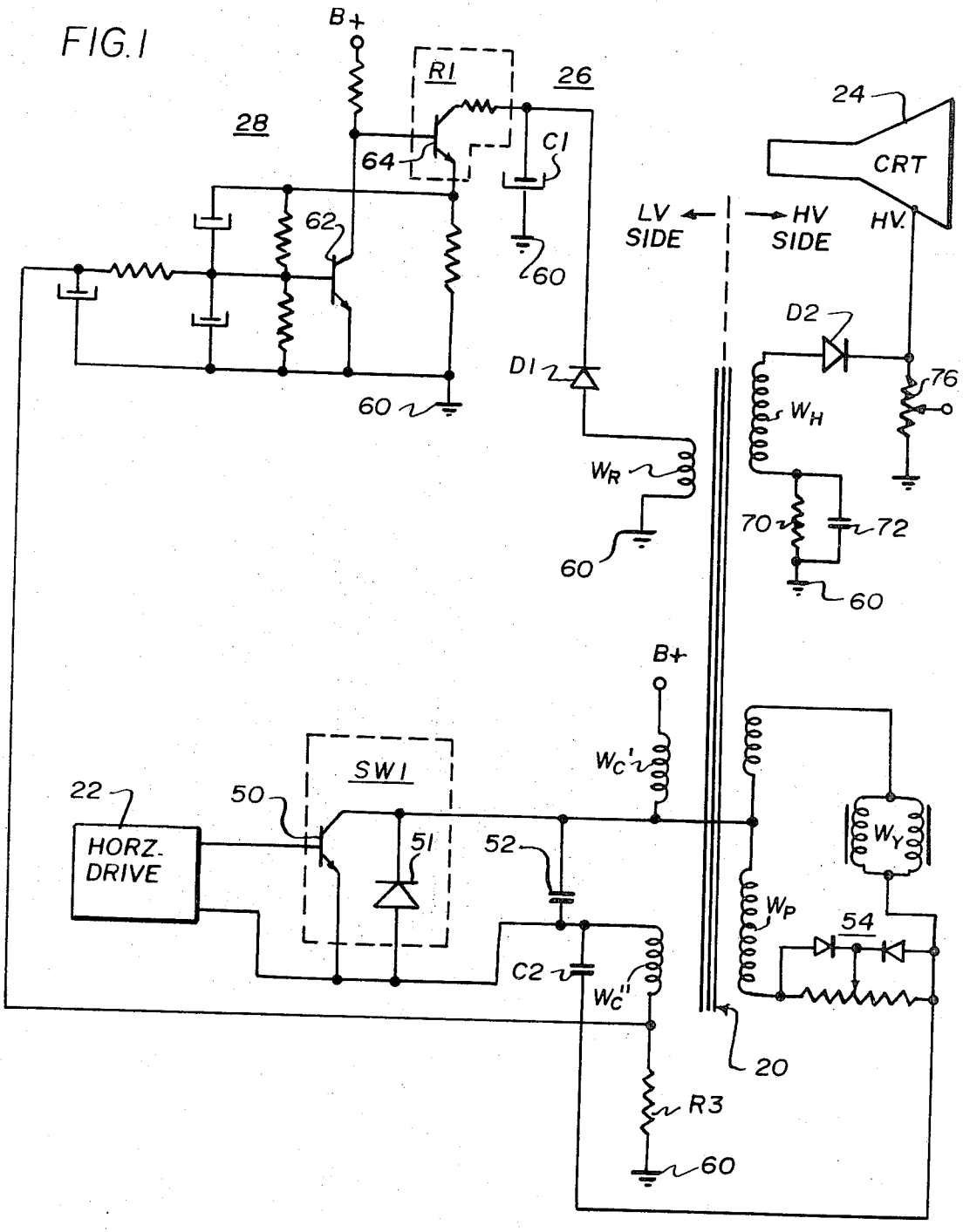

B+
R1
26
28
64
C1
62
60
24
CRT
LV SIDE
HV SIDE
HV.
D2
D1
76
W_H
W_R
70
72
60
B+
W_C'
SW1
22
50
51
52
HORZ. DRIVE
W_Y
W_P
54
C2
W_C''
20
R3
60

FIG.2

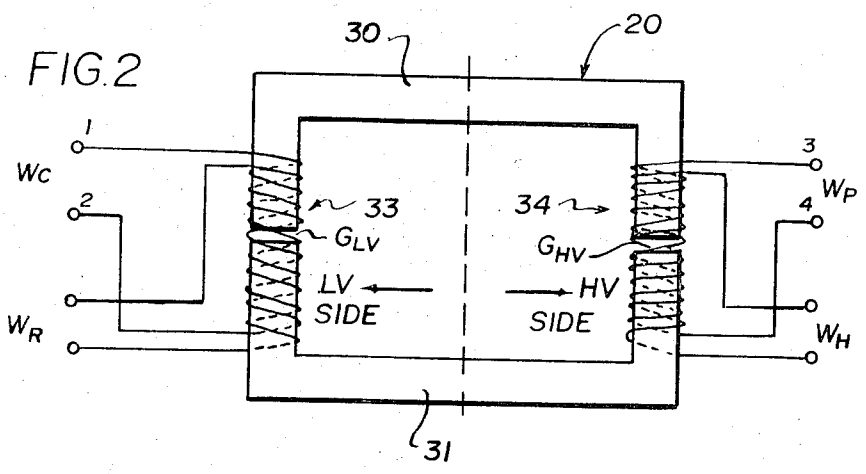


FIG.3

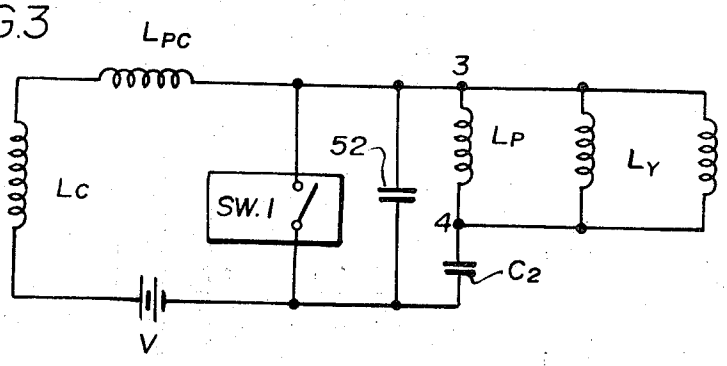


FIG.4

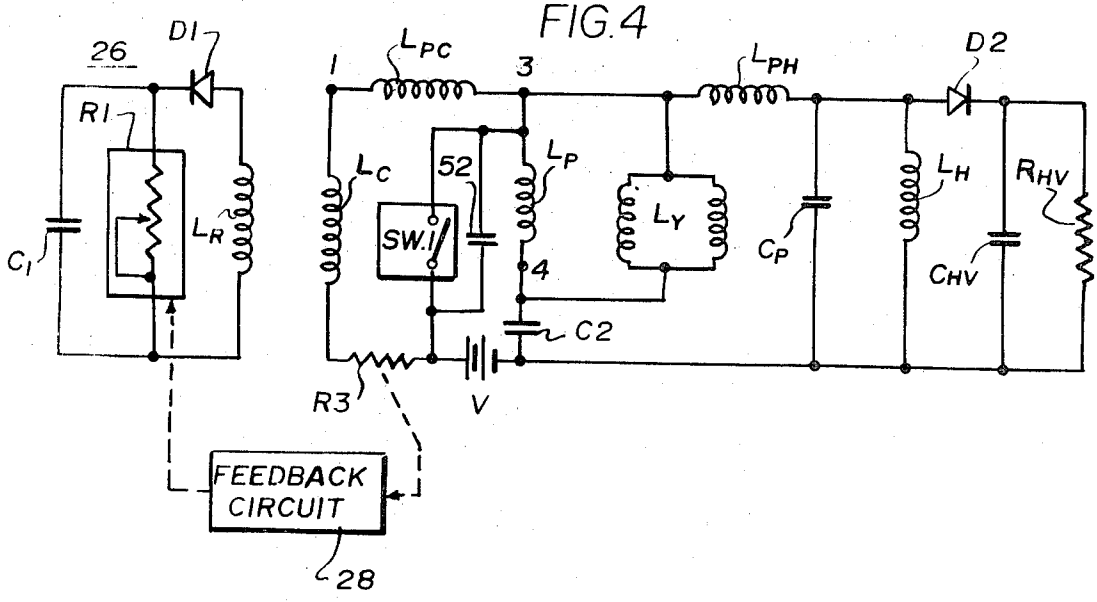


FIG. 5A I_{L_P}

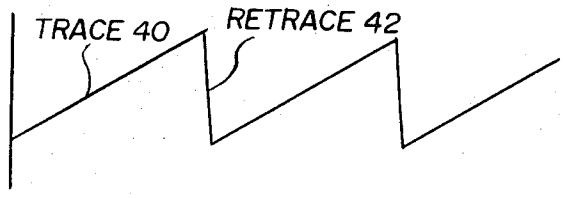


FIG. 5B I_{L_C}

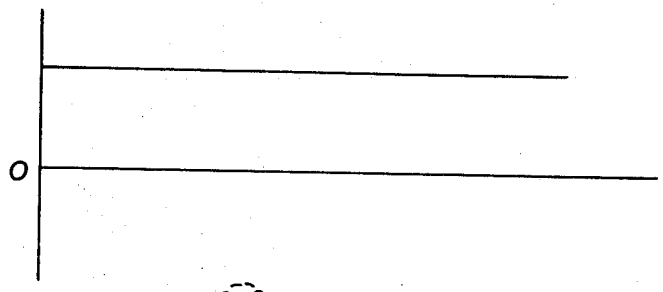


FIG. 5C V_{L_P}

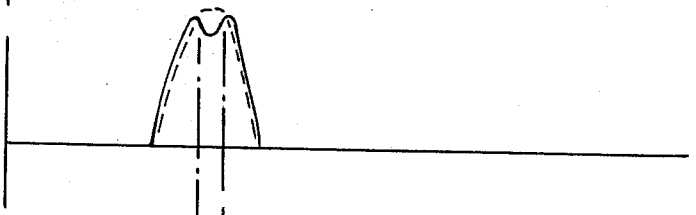


FIG. 5D $V_{L_{PH}}$

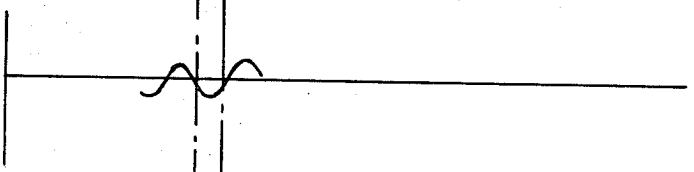


FIG. 5E V_{L_H}

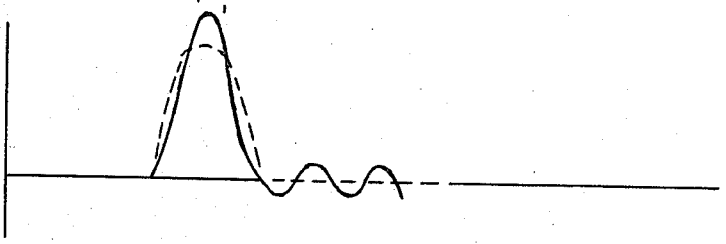
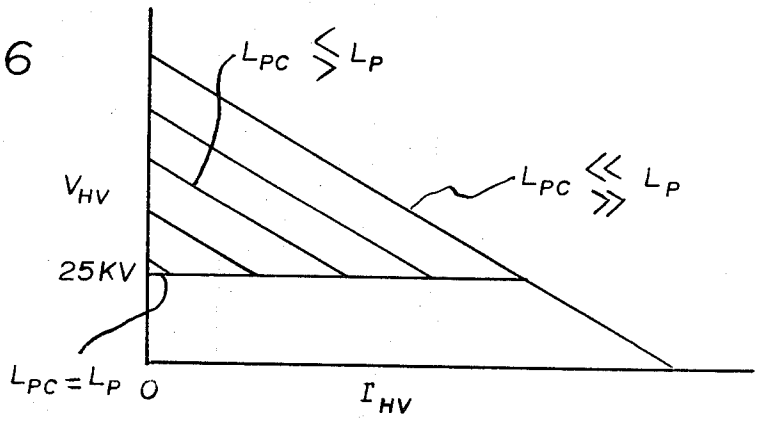


FIG. 6



HIGH VOLTAGE REGULATOR

BACKGROUND OF THE INVENTION

This invention relates to a horizontal flyback transformer and associated regulating circuit.

To regulate the high voltage output from a horizontal flyback transformer, it has been known to provide a regulating winding coupled to a regulating circuit which produces variable loading under control of a sensed characteristic. Typically, the auxiliary or regulating winding is located on the same core leg of the flyback transformer as is the high voltage winding. Examples of such prior systems are illustrated in the U.S. Pats. to Schade No. 2,843,796, Shulman et al. U.S. Pat. No. 3,134,045, and Knight U.S. Pat. No. 3,519,741. While the use of a regulating winding satisfactorily controls the high voltage output, prior systems have required a large driving current from the horizontal output stage.

The value of leakage inductance between various flyback windings has been used for regulation and to control the harmonic tuning of the high voltage circuit. The leakage inductance of a transformer is equal to the number of leakage flux linkages per unit of current, and is approximately constant despite the nonlinearities involved in self inductance and mutual inductance as a function of flux or current. Leakage flux links only a particular winding, as distinguished from mutual inductance which links a plurality of windings. The leakage inductance between the high voltage or tertiary winding and the primary winding has been adjusted for harmonic ringing, as shown for example by U.S. Pat. to Brooks No. 3,132,284. However, between the other windings of a flyback transformer, the leakage inductance is generally designed to be as small as possible, as indicated by U.S. Pat. to Rietveld et al. No. 3,500,116.

Harmonic tuning of the high voltage winding has also been utilized to increase high voltage. The above noted Rietveld et al. U.S. Pat. No. 3,500,116 utilizes fifth harmonic tuning. The above noted Brooks U.S. Pat. No. 3,132,284 utilizes third harmonic ringing to get increased high voltage, by controlling the leakage inductance between the high voltage or tertiary winding and the primary winding.

SUMMARY OF THE INVENTION

In accordance with the present invention, an improved horizontal flyback transformer and regulating circuit are disclosed. A regulating winding is carried on the same core leg as a driving choke winding, and on an opposite leg from the high voltage and primary or deflection windings, to reduce the driving current necessary for the flyback transformer.

Also to reduce the power input requirements, the current flow in the driving choke winding is forced to be of generally steady value, by control of the leakage inductance between the driving choke winding and the primary winding. Unlike prior flyback transformers in which the leakage inductance is generally selected to be as low as possible, the above noted leakage inductance is desirably made equal to the inductance of the primary winding. The value of the leakage inductance is controlled by the use of air gaps and coil turns. The flyback transformer also incorporates various techniques to control harmonic tuning of the high voltage circuit.

One object of the present invention is the provision of an improved horizontal flyback transformer having a regulating winding located on a core leg opposite a core leg carrying a high voltage winding and/or a deflection winding.

Another object of this invention is the provision of a horizontal flyback transformer which controls leakage inductance by the use of air gaps in the core legs and coil turns, and desirably makes the leakage inductance equal to the inductance value of one of the windings.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a novel horizontal flyback transformer and associated regulating circuit, as incorporated in the horizontal stage of a television receiver;

FIG. **2** diagramatically illustrates the mechanical construction of the novel horizontal flyback transformer;

FIG. **3** illustrates a simplified equivalent circuit of the applicant's horizontal flyback transformer and regulating circuit;

FIG. **4** illustrates a detailed equivalent circuit of the applicant's horizontal flyback transformer and regulating circuit;

FIGS. **5A**, **5B**, **5C**, **5D**, and **5E** illustrate current and voltage waveforms at various locations in the circuits of FIGS. **3** and **4**; and

FIG. **6** is a graph of voltage versus current for the high voltage or tertiary winding of the flyback transformer, illustrated for several values of leakage inductance.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Turning to FIG. **1**, the horizontal output stage of a television receiver is illustrated, including a horizontal flyback transformer **20** carrying at least four windings W. A horizontal driving or choke winding W_C provides horizontal scan current to the flyback transformer and is driven by the horizontal output of a switch **SW1** controlled by a horizontal drive output stage **22.** A deflection of primary winding W_P provides horizontal scan current to a horizontal deflection coil or yoke winding W_Y which is associated with the image reproduction device, as a cathode ray tube (CRT) **24.** A tertiary or high voltage winding W_H produces high voltage pulses which are rectified by a high voltage diode **D2** for coupling to the high voltage HV anode of the CRT **24.**

To regulate the value of high voltage, a regulating winding W_R is coupled to a variable loading or regulating circuit **26** which variably damps the regulating winding W_R. The variable damping is controlled by a feedback circuit **28** which is coupled to a sensing resis-

tor R3 located in series with the driving choke winding W_C.

The mechanical construction of the horizontal flyback transformer **20** is illustrated in FIG. **2.** The ends of a C-shaped ferrite core **30** are spaced from the ends of a C-shaped ferrite core **31** so as to produce a pair of air gaps G in an otherwise closed magnetic loop. The air gap which spaces the pair of facing ends in a low voltage leg **33** of the magnetizable core is designated G_{LV}. Conversely, the air gap which separates the facing ends of a high voltage leg **34** is designated G_{HV}. On low voltage leg **33,** the driving choke winding W_C and the regulating winding W_R are concentrically wound. On the high voltage leg **34,** the primary winding W_P is wound in a known manner. The high voltage winding W_H is concentrically wound over the primary winding W_P, and may be spaced therefrom by an insulating spacer, in order to control the leakage inductance between windings W_H and W_P and to insulate the high voltage winding W_H from winding W_P. The leakage inductance of windings located on opposite core legs is controlled by the spacing of the air gaps G and coil turns.

The operation of applicant's flyback transformer and regulating circuit may be understood with reference to the simplified equivalent circuit shown in FIG. **3.** All inductances L carry a subscript to identify the particular winding W which is represented by that inductance value. Thus L_Y represents the yoke inductance, L_P represents the primary winding inductance, and L_C represents the driving choke winding inductance.

L_{PC} represents the leakage inductance between windings W_P and W_C. The flyback transformer **20** is purposely designed to have a large leakage inductance L_{PC}, and preferably of a value equal to the inductance LP. The value of the leakage inductance in turn is controlled by the physical dimensions of the flyback transformer, including the spacing of the gaps G and coil turns, which illustratively may be 0.030 inches.

The remaining components of the equivalent circuit of FIG. **3** are an S-shaping capacitor C**2,** and a voltage supply V. A switch SW**1** periodically opens and closes at a rate determined by the horizontal driving frequency. The circuit functions as follows. During the horizontal trace interval, switch SW**1** is closed and current flows from the voltage source V through L_C and L_{PC}. At the beginning of the horizontal retrace interval, SW**1** is open and the energy stored in L_P during the trace interval by inductive coupling from L_C is transferred to capacitor **52** and back to L_P with polarity reversed by retrace tuning.

Referring to FIG. **5**A, the horizontal driving current I through L_P is represented by I_{L_P}. This current consists of a sawtooth wave including a trace portion **40** and a retrace portion **42.** The current through L_P causes the yoke current to be of proper form to horizontally deflect the electron beam of the CRT in order to form a raster.

In a conventional flyback transformer, the winding W_C is normally tightly coupled to winding W_P, and hence the current through L_C is normally substantially the same as through L_P. However, in applicant's circuit, the leakage inductance L_{PC} is selected to be substantially higher than normal, and preferably equal to L_P. This causes a substantially constant current I in coil L_C, as represented by the current curve I_{L_C} in FIG. **5**B. It has been determined empirically that the closer inductance L_{PC} approaches inductance L_P, the more steady is the current flow in winding W_C. This steady current flow in turn represents minimum energy requirements for maintaining current flow in the driving choke winding, and thus serves to lower the energy requirements of the flyback transformer and associated circuits.

In FIG. **4,** the equivalent circuit of FIG. **3** has been expanded to illustrate further components. L_H represents the inductance of the tertiary or high voltage winding, and L_{PH} represents the leakage inductance between the windings L_H and L_P. The leakage inductance L_{PH} is controlled by the spacing between the concentrically wound coils W_H and W_P. Capacitance C_P represents the distributed capacitance of coil W_P.

To increase high voltage, natural transformer tunings are resonated at the third harmonic frequency of the retrace period. The circuit is then mistuned by capacitor **52** to the high frequency side by a slight amount, L_{PH} and C_P are resonated at the third harmonic frequency of the retrace period. The voltage across L_H is shown in FIG. **5**E and V_{L_H}. The leakage inductance L_{PH} rings at the third harmonic frequency of the retrace period, as illustrated in FIG. **5**D. The voltage $V_{L_{PH}}$ adds to the voltage across L_H, illustrated by the dotted line in FIG. **5**E, so as to produce the resultant shown by the solid line in FIG. **5**E. The dotted line in FIG. **5**C represents the voltage which would occur across L_P without the ringing effect of L_{PH}.

Returning to the equivalent circuit of FIG. **4,** D**2** represents the high voltage diode coupled to the high voltage winding W_H. Capacitor C_{HV} represents the filter capacitance for the high voltage supply, and resistance R_{HV} represents the resistance of the high voltage load. Both components C_{HV} and R_{HV} include lumped circuit components located between diode D**2** and the CRT anode, as well as internal and distributed components associated with the CRT.

In the equivalent circuit, a sensing resistor R**3** is located to produce a feedback voltage which is sensed by a feeback circuit **28.** The output of the feedback circuit **28** controls a variable resistor R**1** which is located in a regulating network **26** which includes a capacitor C**1,** an inductance L_R of the regulating winding W_R, and a diode D**1.** The regulating network **26,** under control of the feedback circuit **28,** acts as a variable load which maintains a constant high voltage despite changes in beam current in the CRT.

Unlike prior circuits, the regulating winding W_R is located on the LV side of the flyback transformer **20,** see FIG. **2,** reducing the driving current requirements. The voltage developed across current sensing resistor R**3** is due to the current $I_{L_C'}$ shown in FIG. **5**B. This sensing or feedback voltage is utilized to vary the resistance of R**1.** The resulting regulation characteristic of the circuit is illustrated in FIG. **6.** As leakage inductance L_{PC} approaches in magnitude inductor L_P, the regulation approaches the horizontal line shown at 25 kilovolts. Thus, excellent regulation characteristics are produced by controlling the spacing of the air gaps G the coil turns and the other mechanical dimensions of the flyback transformer **20** so as to have L_{PC} equal to L_P.

Returning to FIG. **1,** the components which produce the equivalent circuit of FIG. **4** will now be described in detail. The driving choke winding W_C is divided into two portions, with switch SW**1** being located between a section top W_C' and a bottom section W_C''. The switch SW**1** takes the form of a transistor **50** and

damper diode **51** coupled across a retrace capacitor **52** which is located between coils W_C' and W_C''. The retrace capacitor **52** has a value which controls the third harmonic tuning.

Coil W_C' is coupled between a source of positive DC potential, or B+, and one side of the retrace capacitor **52.** The lower coil W_C'' is coupled between the opposite side of retrace capacitor **52** and through sensing resistor **R3** to a source of reference potential or ground **60.** Capacitor **C2** forms the S-shaping capacitor for the horizontal yoke coil W_Y.

Primary coil W_P is coupled through a horizontal centering network **54** to the horizontal yoke coil W_Y. Additional centering and other correction networks, such as for pincushion and the like (not illustrated), may be associated with horizontal yoke coil W_Y, as desired. For clarity, the additional correction circuits are not illustrated in FIG. **1.**

Drive current through the coils W_C passes through resistor **R3,** and the voltage drop thereacross is coupled to a transistor **62** in the feedback circuit **28.** Transistor **62** is DC coupled to transistor **64,** which forms resistance **R1.** The value of resistance, as controlled by the biasing of transistor **62,** controls the damping or variable loading provided by regulating coil W_R.

On the high voltage side of flyback transformer **20,** the high voltage coil W_H is coupled through the parallel combination of a resistor **70** and capacitor **72** to ground **60,** and through high voltage diode **D2** to the anode of the CRT **24.** A focus resistor **76** is located between the high voltage lead and ground **60.** Additional components (not illustrated for clarity) may be provided as desired.

1. In a television receiver including horizontal scanning means having horizontal transformer with a driving winding coupled to a horizontal drive stage and a high voltage winding for developing a high voltage of varying current, a regulating system, comprising:

first and second core legs forming a transformer core for said horizontal transformer, said driving winding and said regulating winding being wound on said first core leg,

said high voltage winding being wound on said second core leg, and

circuit means for variably loading the regulating winding to maintain the high voltage developed by said high voltage winding at an approximately constant level.

2. The regulating system of claim **1** wherein said circuit means includes sensing means for generating a sensing signal which varies with changes in high voltage current, and feedback means coupled between said sensing means and said regulating winding for variably loading the regulating winding in response to said sensing signal.

3. The regulating system of claim **2** wherein said sensing means comprises resistive means in series with said driving winding for developing thereacross a voltage drop corresponding to said sensing signal.

4. The regulating system of claim **3** wherein said feedback means comprises semiconductor means for establishing a variable resistance, first network means for coupling said resistive means to said semiconductor means to control the resistance thereof, and second network means for coupling said regulating winding to said semiconductor means.

5. The regulating system of claim **4** wherein said second network means comprises a diode poled to pass current flow in only one direction.

6. The regulating system of claim **1** wherein said driving winding is concentric with said regulating winding.

7. The regulating system of claim **6** wherein said horizontal transformer further includes a deflection winding coupled to a horizontal deflection coil, said deflection winding being wound on said second core leg and concentric with said high voltage winding.

8. The regulating system of claim **7** including control means for establishing between said driving winding and said deflection winding a leakage inductance of a value approximately equal to the inductance of said deflection winding.

9. The regulating system of claim **8** wherein said control means comprises a pair of air gaps respectively located in said first and second core legs.

10. In a television receiver including horizontal scanning means having a flyback transformer with a high voltage winding for developing high voltage of varying current and a deflection winding coupled to a horizontal deflection coil, a regulating system, comprising;

first and second core legs forming a transformer core for said flyback transformer, said high voltage winding and said deflection winding being wound on said second core leg,

a regulating winding wound on said first core leg, and

circuit means for variably loading the regulating winding to regulate the high voltage developed by said high voltage winding.

11. The regulating system of claim **10** wherein said high voltage winding is concentric with said deflection winding, and said flyback transformer includes a driving winding wound on said first core leg and coupled to a horizontal drive stage.

12. The regulating system of claim **11** wherein said circuit means includes a feedback resistor in series with said driving winding, and means responsive to the voltage drop across said feedback resistor for controlling a variable resistance in series with said regulating winding.

13. The regulating system of claim **12** wherein at least one of said core legs includes an air gap having a size to cause the leakage inductance between the driving winding and the deflection winding to be approximately equal to the inductance of the deflection winding.

14. In a television receiver including a horizontal output stage, a horizontal deflection coil, and a horizontal scanning circuit for coupling the horizontal output stage to the horizontal deflection coil, the improvement comprising:

horizontal transformer means having a driving winding coupled to said horizontal output stage and a deflection winding coupled to said horizontal deflection coil, and

control means for establishing between said driving winding sand said deflection winding a leakage inductance of a value approximately equal to the inductance of said deflection winding.

15. The improvement of claim **14** wherein said horizontal transformer means has a magnetizable core generally forming a closed loop, and said control means

comprises an air gap breaking the closed loop of the magnetizable core.

16. The improvement of claim **15** wherein said magnetizable core comprises two sections each of generally C-shape and having a pair of ends, and said air gap comprises a pair of air gaps separating the spaced adjacent ends of the two sections.

17. The improvement of claim **16** wherein said magnetizable core includes first and second core legs with one of said air gaps being located in said first core leg and the other of said air gaps being located in said second core leg, said driving winding being wound about said first core leg and said deflection winding being wound about said second core leg.

18. The improvement of claim **17** wherein said horizontal transformer means includes a regulating winding wound on said first core leg, a high voltage winding wound on said second core leg, and circuit means for variable loading the regulating winding to maintain an approximately constant level of high voltage from said high voltage winding.

19. The improvement of claim **14** wherein said horizontal transformer means includes a regulating winding and a high voltage winding, magnetizable core means having at least a first core leg and a second core leg, said deflection winding being wound on said first core leg, and at least one other of said windings being wound on said second core leg.

20. The improvement of claim **19** wherein said high voltage winding is wound on said first core leg and is concentric with said deflection winding, said regulating winding is wound on said second core leg, and said driving winding is wound on said second core leg and is concentric with said regulating winding.

21. The improvement of claim **20** wherein said control means comprises a pair of air gaps each located in a different one of said first and second core legs.

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