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Blanchard

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[54] **FERRO-RESONANT HIGH VOLTAGE SYSTEM**

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[52] U.S. Cl. **315/411,** 336/178
[51] **Int. Cl.** **H01j 29/70**
[58] **Field of Search**......... 315/27 TD, 27 XY, 27 R, 315/28–29, 18, 25; 336/178

[56] **References Cited**

UNITED STATES PATENTS

2,451,026	10/1948	Friend	315/27 XY
2,606,304	8/1952	Moore	315/27 XY
3,205,401	9/1965	Flyer et al.	315/27 XY
3,609,446	9/1971	Hursh	315/27 TD
3,717,789	2/1973	Wolber	315/27 XY

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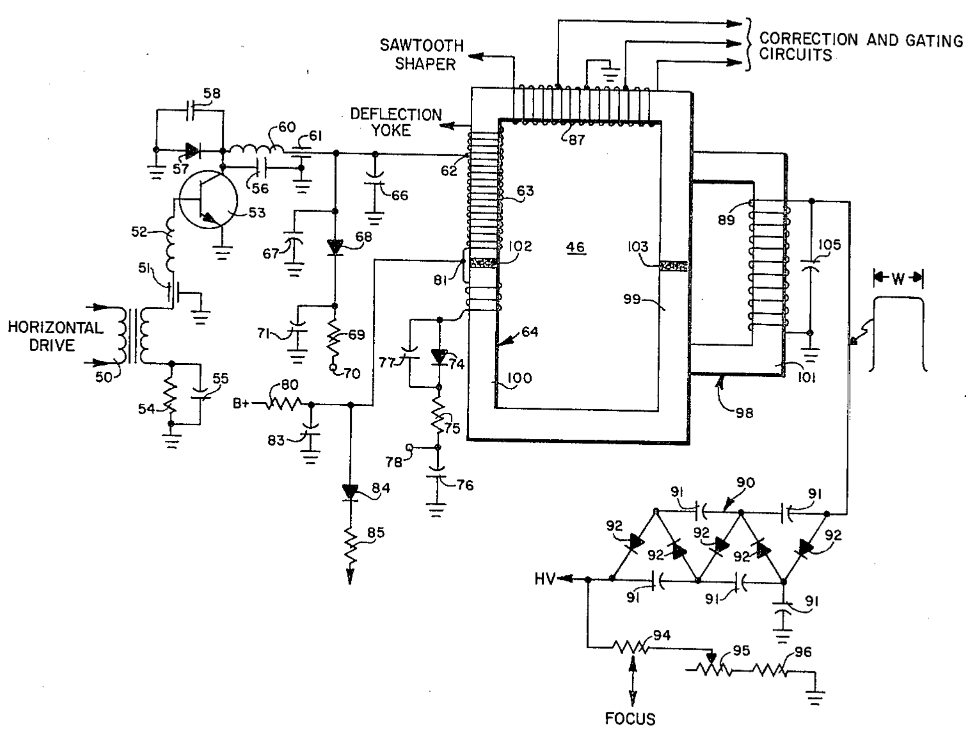
[57] **ABSTRACT**

A cathode ray tube high-voltage supply system is of the type in which sawtooth-shaped pulses are developed in a first transformer winding in order to produce a scanning waveform in a deflection yoke on the tube. So-called fly-back energy, developed as a result of magnetic field collapse in the yoke during retrace, is utilized, in turn, to produce high-voltage output pulses in another winding to which a load is coupled that requires a broad, generally-square pulse shape. The first winding is wound upon a first ferromagnetic core that defines a non-saturating magnetic circuit. The other winding is wound upon a second ferromagnetic core which, together with a portion of the first core, defines a second magnetic circuit that saturates in operation. A capacitor included in the load is coupled across the other winding and controls the energy in said second magnetic circuit in such a manner as to supply the load with pulses that are broad and have a generally-square shape.

13 Claims, 3 Drawing Figures



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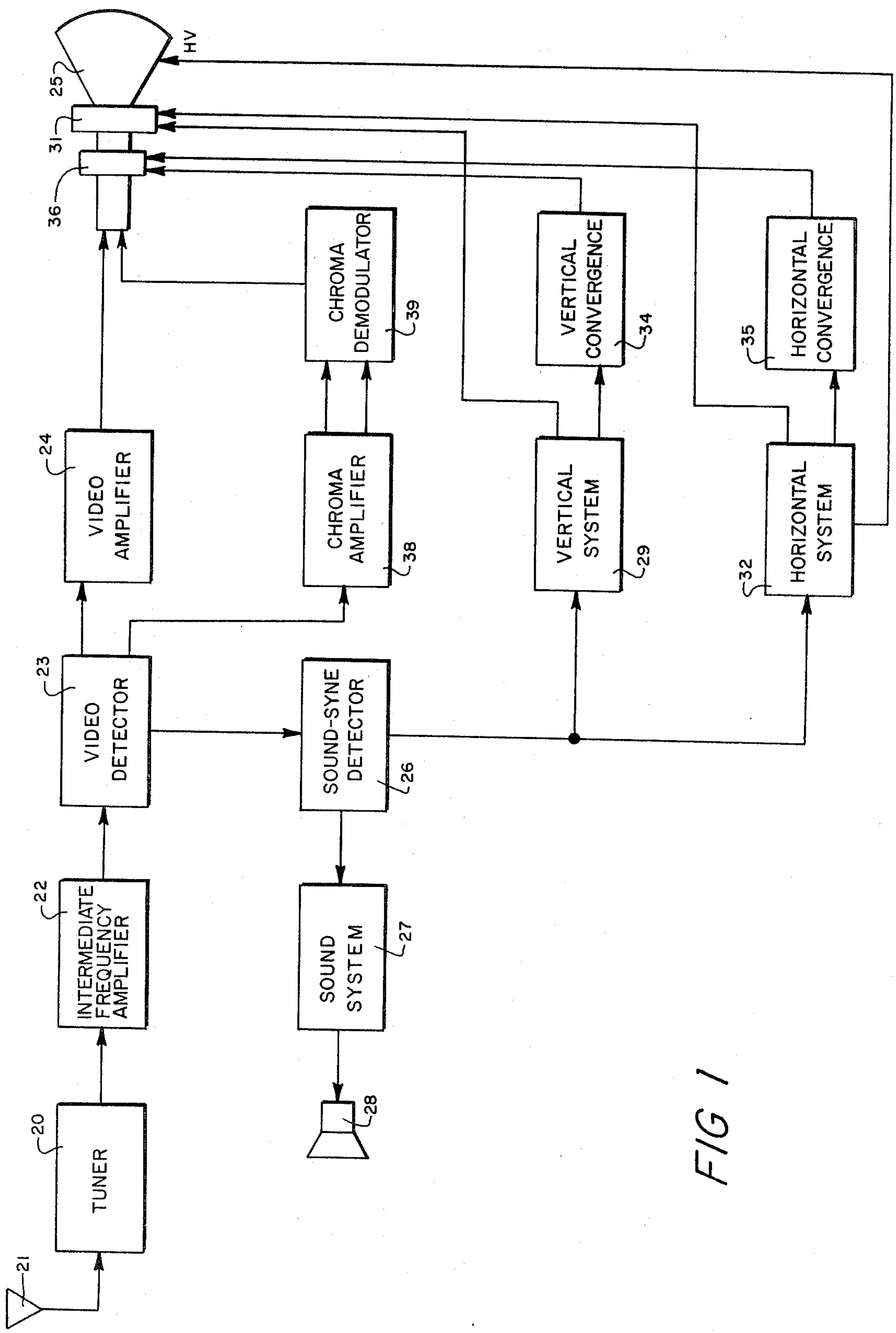


FIG 1

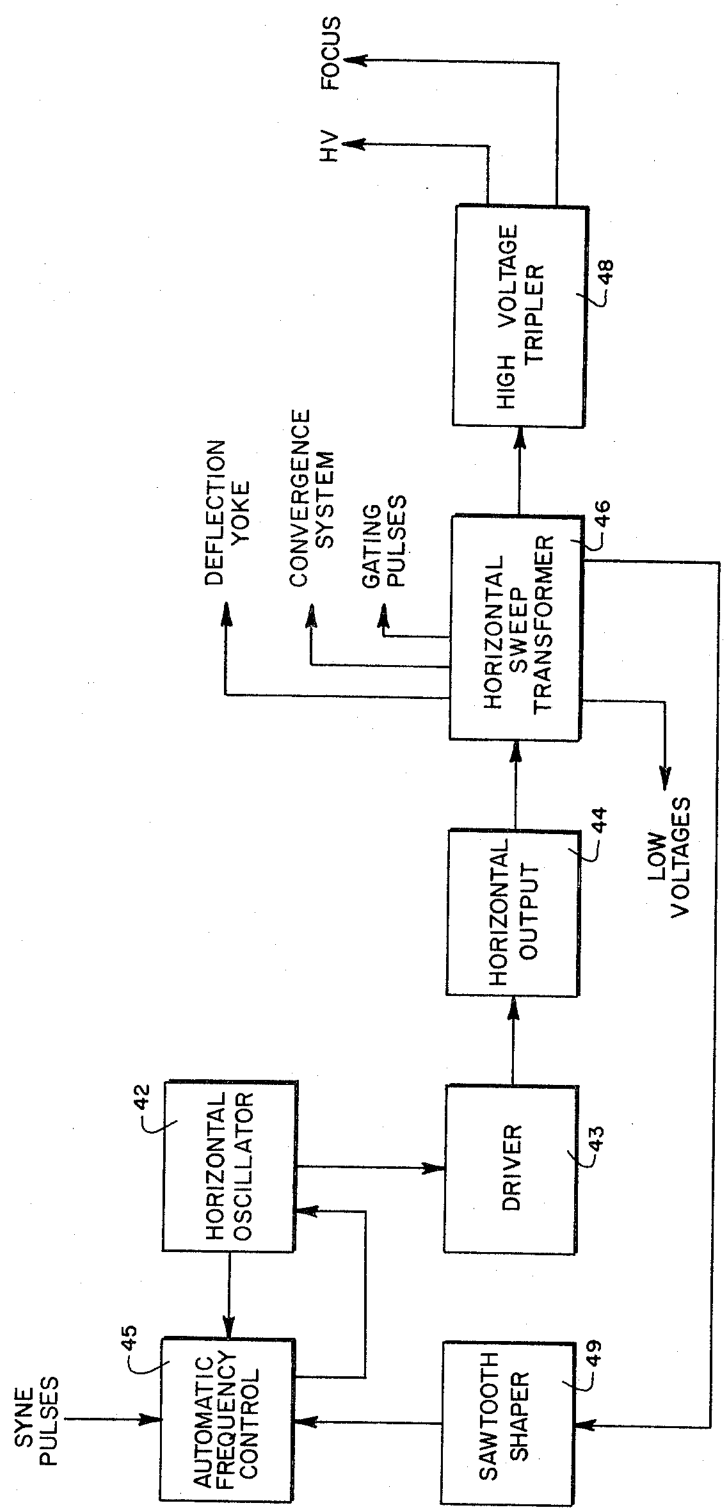
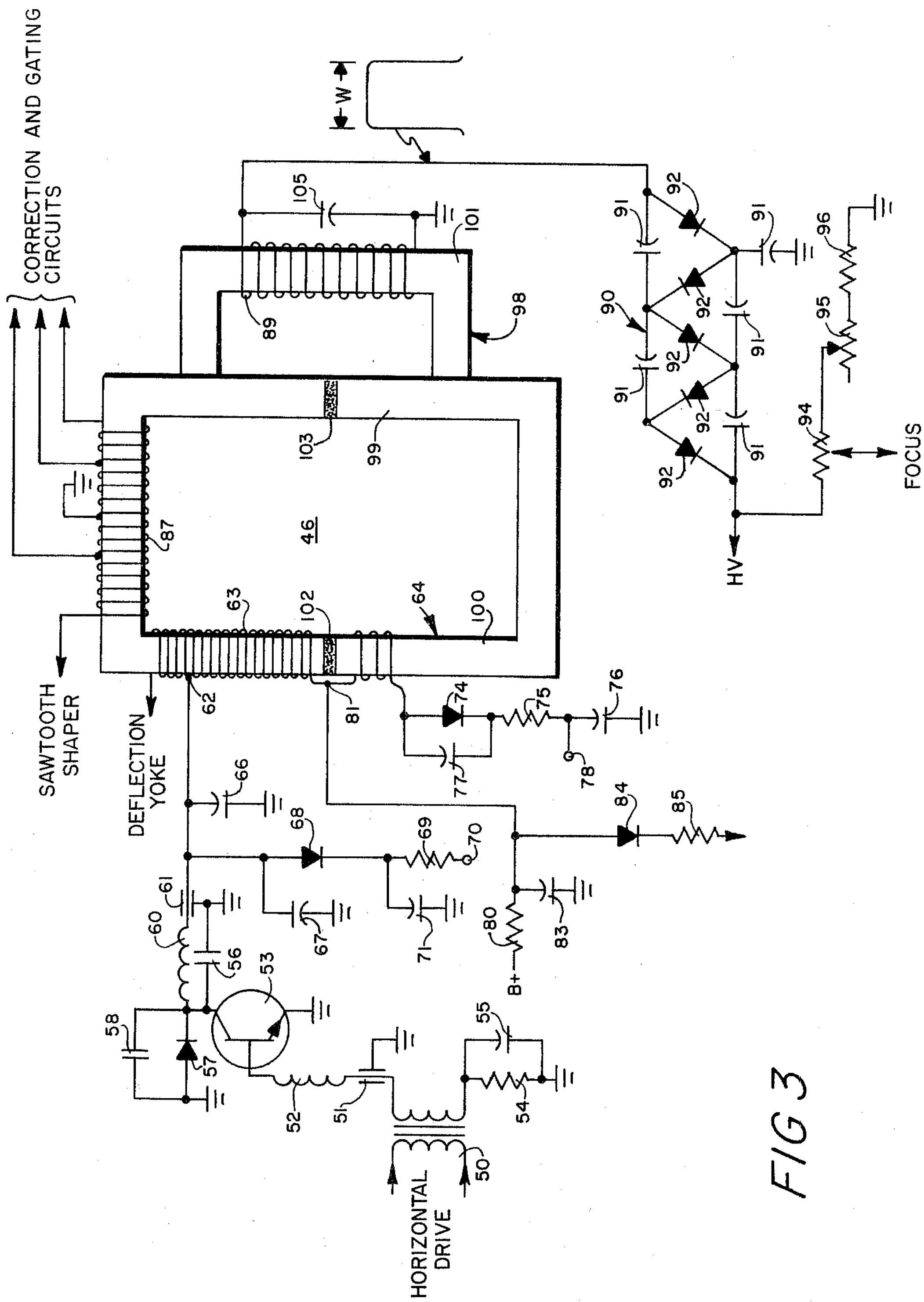

FOCUS
HV
HIGH VOLTAGE TRIPLER
48
DEFLECTION YOKE
CONVERGENCE SYSTEM
GATING PULSES
HORIZONTAL SWEEP TRANSFORMER
46
LOW VOLTAGES
HORIZONTAL OUTPUT
44
HORIZONTAL OSCILLATOR
42
DRIVER
43
SYNE PULSES
AUTOMATIC FREQUENCY CONTROL
45
SAWTOOTH SHAPER
49

FIG 2


CORRECTION AND GATING CIRCUITS
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DEFLECTION YOKE
HORIZONTAL DRIVE
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FIG 3

FERRO-RESONANT HIGH VOLTAGE SYSTEM

BACKGROUND OF THE INVENTION

The present invention pertains to high voltage supplies for cathode ray tubes. More particularly, it relates to such systems which also supply scanning energy to a deflection yoke and utilize counter energy developed by the yoke during the retrace intervals to produce output pulses from which the high voltage is derived.

Cathode ray tubes such as those commonly employed in television receivers require a comparatively high final anode voltage in order adequately to develop the reproduced image. For example, color image reproducers frequently require a final anode voltage of between 25 and 30 kilovolts. Even comparatively small-screen monochrome image reproducers still necessitate the development of high voltages measured in terms of kilovolts, a level many times that of any other voltage required for energizing the different stages in the associated receiver. Conveniently, it has been the practice for many years to derive the necessary energy for development of the high voltage from the collapse of the magnetic field in the deflection yoke during each retrace interval of the horizontal scanning function. Typically, generally square-shaped driving pulses, repeating at the horizontal scanning rate, are applied to a primary winding on what is called the horizontal-output or flyback transformer. That winding may serve as an auto-transformer and may have a tap to which the deflection yoke is connected. During the retrace interval, a surge of energy is fed back from the yoke to the winding as a result of the collapse of the magnetic field in the yoke. This surge of energy produces an output in what is often referred to as a tertiary winding on the same transformer core and which is arranged so as to effect a substantial step-up in the output pulse voltage level. The tertiary winding may either be a continuation of the primary winding, thus functioning still further as an auto-transformer, or be a separate winding wound upon the core of the transformer. In any event, the stepped-up output pulses are then rectified and stored in a filter capacitor from which the unidirectional high voltage is supplied to the final anode of the cathode ray tube. Also conventionally wound upon the core of the transformer is a secondary winding which is employed to develop waveforms employed elsewhere in the television receiver to perform variable correction, compensation and gating functions.

In many cases, the entire voltage step-up has been achieved in the transformer itself by means of appropriate selection of the ratio of tertiary to primary winding turns. With the peak level voltage in the transformer itself thus at a very high level, it has been necessary to attend careful to the insulation qualities within the transformer. Even the eventual dielectric breakdown has too often been encountered and resulted in a somewhat expensive replacement.

To the end of reducing the high voltage level necessary to be reached in the transformer itself, another approach has been to operate the transformer so that the peak tertiary voltage level is of a substantially lower value and then employ a separate voltage multiplier to develop the ultimately required high voltage level. In a typical example the level of the output pulses from the tertiary winding of the transformer is 9 kilovolts, and a voltage tripler circuit is then employed to increase that level to the 27 kilovolts required by an associated color image reproducer. Conventionally, the voltage multiplier is a ladder arrangement of diodes and capacitors with the diodes serving to rectify the output pulse energy and the capacitors accumulating charges while individually operating in succession so as to step-up the voltage. In an effort to achieve a longer charging time for the multiplier capacitors, and thus obtain better regulation, it has been recognized that it is desirable to produce a significant fifth harmonic component in the output pulses. In consequence, they tend to be flatter and broader. In one approach reasonably successful for that purpose, the tertiary winding is link coupled to the primary winding with the link itself being tuned to the third harmonic of the scanning frequency.

While progress thus has been made in the attainment of improved high-voltage supplies of the kind discussed, a number of problems are still encountered. In at least some cases, ringing during the scanning interval causes the voltage multiplier to conduct during peak negative tips of the ringing cycle, so as to result in a non-linear behavior of the anode regulation curve. Another cause for undesired decrease in anode voltage, over that of which the system is capable, is that the flat portion of the peak positive output pulse still may have a duration of only a few microseconds. Such limited conduction time restricts the amount of charge that can be transferred into a voltage multiplier by reason of the finite time constant associated with the capacitors therein as well as the forward impedances of the diodes and the output impedance of the tertiary winding. A still further cause of degradation of anode voltage regulation, related to the other two, is that the output impedance of the low-voltage power supply generally must be increased in order to minimize picture size variation stemming from the anode voltage variation.

In one specific approach utilizing a voltage multiplier and in which fifth harmonic content is included in the output pulses, the system includes a saturable reactor regulator which stores energy in the reactor magnetic field, during scanning time, that is returned to the transformer during retrace time so as to increase the load current. The result is the production of a higher peak-positive tertiary or output voltage for charging the voltage multiplier capacitors. However, it is found that detuning of the harmonics occurs and the problem of maintaining constant picture size often becomes severe. Such detuning is a result of a change in primary inductance with anode current change that produces an unbalance in the tuning of the transformer. This contributes to non-minimum ring conditions during scanning as well as a non-linear regulation curve at required anode currents. In addition, the regulating range is limited by the change in inductance of the reactor between the minimum and maximum energy demands of the load. Moreover, energy exchange occurs only during the peak-positive tertiary output pulse in the retrace interval. There is no increase in energy available during the scanning time interval.

OBJECTS OF THE INVENTION

It is, therefore, a general object of the present invention to provide a new and improved cathode ray tube high-voltage supply system generally of the foregoing character but in which problems such as those just discussed are overcome or at least significantly minimized.

Another object of the present invention is to provide a new and improved system of the foregoing character which optimizes anode voltage regulation characteristics while yet maintaining simplicity in the design of the horizontal deflection system and without requiring extensive changes in design of the associated image reproducing system.

A further object of the present invention is to provide a new and improved cathode ray tube high-voltage supply system of a kind including a voltage multiplier which is fed with output pulses that exhibit minimum ringing during associated scanning intervals and a flat, wide positive peak in order to obtain a linear change in anode voltage with change in anode current as well as to obtain substantial charging of capacitors in the multiplier during the period of rectification.

A still further object of the present invention is to provide a new and improved cathode ray tube high-voltage supply system which exhibits a comparatively low output impedance and develops output pulses characterized by having a constant peak-to-peak voltage excursion that is independent of minor low-voltage supply variations.

One specific object of the present invention is to provide a supply system of the foregoing character which provides an output waveform of a symmetrical flat-topped shape while yet preserving with minimum distortion an asymmetrical shape of developed input pulses.

A related object of the present invention is to provide a cathode ray tube high-voltage supply system which provides overload protection for the primary driving source.

SUMMARY OF THE INVENTION

The invention thus pertains to a cathode ray tube high-voltage supply system in which sawtooth-shaped current pulses are developed in a first transformer winding in order to produce a scanning waveform in a deflection yoke on the cathode ray tube. Energy developed, as a result of collapse of the magnetic-field in the deflection yoke, is utilized, in turn, to produce high-voltage output pulses in a second winding. To the end of generating a broad generally-square pulse shape for application to the load coupled to the second winding, a first closed magnetic circuit is non-saturating in response to development of the sawtooth-shaped pulses and includes a first ferromagnetic core upon which the first winding is wound. A second closed magnetic circuit, on the other hand, saturates in response to the energy developed as a result of the field collapse in the deflection yoke and includes only a portion of the first core together with a second ferromagnetic core upon which the second winding is wound. Finally, a capacitor, included in the load, is coupled across the second winding. The capacitor has a value enabling the current cycles in the second winding to coincide with the current cycles in the first winding sufficiently that the yoke field collapse initiates saturation reversal in the second core.

BRIEF DESCRIPTION OF THE DRAWINGS

The features of this invention which are believed to be novel are set forth with particularity in the appended claims. The invention, together with further objects

and advantages thereof, may best be understood, however, by reference to the following description taken in conjunction with the accompanying drawings, in the several figures of which like reference numerals identify like elements, and in which:

FIG. **1** is a block diagram of a color television receiver in which the present invention is embodied;

FIG. **2** is a more detailed block diagram of the horizontal system included in the diagram of FIG. **1**; and

FIG. **3** is a schematic diagram of a portion of the system of FIG. **2**.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Except for modifications to be particularized in connection with the discussion of FIG. **3**, FIGS. **1** and **2** illustrate, with certain simplifications non-essential to an understanding of the present invention, the various different stages or systems which together constitute a conventional color television receiver. Thus, a tuner **20** selects a composite television signal in a desired channel received by an antenna **21**. Employing the usual superheterodyne technique, tuner **20** converts the signal frequencies in the range of whatever channel is selected to a constant frequency range, and those converted signals are fed to an intermediate-frequency amplifier **22**. The amplified intermediate-frequency signals are then fed to a video detector **23** which develops and supplies a video amplifier **24** with a brightness of luminance signal. The latter, in turn, is supplied as one input to a color image reproducer **25**.

A portion of the amplified intermediate-frequency signal from amplifier **22** also is fed to a sound-sync detector **26** from which an audio signal is derived and amplified by a sound system **27** and fed to a sound reproducer **28**. Detector **26** serves still further by extracting synchronizing information from the intermediate-frequency signals and feeding such information to a vertical system **29** that, in turn, produces a scanning waveform which is fed to a yoke **31** mounted on the neck of reproducer or cathode ray tube **25**. Similarly, synchronizing information from detector **26** is fed to a horizontal system **32** which develops a horizontal scanning waveform which is fed to deflection yoke **31**. The horizontal and vertical scanning waveforms energize respective deflection coils within yoke **31** so as to cause the electron beams to scan an image raster on the faceplate of tube **25** in a pattern composed of a series of horizontal lines successively spaced apart in a vertical direction. Another function of horizontal system **32** is to develop a high-voltage HV which is applied to the final anode of cathode ray tube **25**. To assure the proper landing of the different electron beam components upon their assigned phosphor areas of the faceplate, the receiver also includes respective vertical and horizontal convergence systems **34** and **35**. In each case, a sample of the corresponding vertical and horizontal waveforms is converted to a different, conventionally parabolic, shape and then applied to a convergence yoke **36** also mounted on tube **25**.

Specifically for the reproduction of color, the receiver circuitry is responsive to color-representative information fed from video detector **23** to a chroma amplifier **38**. That information defines both the hue and the saturation in the image to be reproduced and also includes a color reference signal. As standardized in the United States and Canada, the latter takes the form of a burst at 3.58 megahertz which is transmitted along with the information for synchronizing the horizontal scanning function. The frequency and phase of the burst is the same as that of a suppressed carrier in the composite television signal upon which the hue and saturation information are modulated.

One function of chroma amplifier **38** is to segregate out and supply the color reference information or burst signal to a chroma demodulator **39** so that the hue information in the chroma signal, also fed from amplifier **38** to demodulator **39**, is properly demodulated in a manner to produce faithful color-control signals which are fed as another input to cathode ray tube **25** in order to modulate the action of its corresponding plurality of three different electron beams that respectively activate the conventional red, green and blue phosphor areas.

As so far described, the receiver in FIG. **1** is entirely conventional. Of course, it will be understood to include the usual additional features that have been found to be desirable. For example, manually-adjustable controls are provided for the viewer in a typical receiver so that he may selectively adjust such functions as volume, brightness, contrast, tone of the sound and hue of the color. Similarly, the receiver conventionally will include a number of automatic systems for governing such functions as intermediate-frequency carrier amplitude and frequency, amplitude of the burst signal, phase and frequency of the reference signal actually used in operation of chroma demodulator **39** and contrast in the reproduced image. However, the control of such functions is well known and forms no part of the subject matter to which the present description is directed.

FIG. **2** illustrates in more detail the different stages within horizontal system **32** of FIG. **1**. It thus includes a horizontal oscillator **42** the frequency and phase of which is compared in an automatic-frequency control **45** with the incoming synchronizing pulses from detector **26**. Any departure in the operation of oscillator **42** as compared with the synchronizing pulses results in the feeding back from automatic-frequency control **45** of a correcting signal which, thereby, serves to maintain synchronization of oscillator **42** with the received synchronizing information. The signals developed by oscillator **42** are then fed through a driver **43** to a horizontal output stage **44** which develops horizontal output pulses that are fed to a horizontal sweep transformer **46**.

In a manner which, as such, is conventional, sweep transformer **46** develops a number of different output signals. As was also mentioned in connection with FIG. **1**, it produces a horizontal scanning waveform which is applied to the deflection yoke as well as providing a sample of that waveform to the convergence system. In addition, its output signals include gating pulses that are fed to other portions of the overall receiver so as to time operation of different functions, such as automatic-gain control and automatic-chroma control, to occur at desired intervals in the received composite television receiver signal. Furthermore, sweep transformer **46** develops different voltages that are applied to various stages and components in the television receiver. As indicated, these include certain low voltages and, in particular, output pulses which are supplied to a high-voltage tripler **48**. The latter serves to rectify the output pulses as well as to substantially step-up their voltage level so as to produce the very high voltage HV which is applied to the final anode of tube **25**. Tripler **48** also develops a similarly high-level focus voltage that also is applied to cathode ray tube **25**. Additionally included in the system is a sawtooth shaper **49** which receives a sample of the waveform developed in horizontal sweep transformer **46** and feeds it back to automatic-frequency control **45** for the purpose of governing operation of the latter in order to maintain production of the appropriately desired waves of sawtooth shape in transformer **46**.

As illustrated in FIG. **2** and as so far described, the arrangement and functioning of the horizontal system could be entirely in a known manner such as in accordance with that discussed in the introduction. As embodied herein, however, horizontal system **32** is specifically improved in the manner particularized in FIG. **3**. That is, horizontal drive pulses from driver **43** are applied across the primary winding of an isolation transformer **50** from one end of the secondary of which those pulses are fed through a grounded feed-through capacitor **51** and a choke **52** to the base of an NPN transistor **53**. The other end of the secondary winding of transformer **50** is returned to ground through a resistor **54** by-passed by a capacitor **55**. The emitter of transistor **53** is returned to ground, while its collector is shunted to ground by a capacitor **56** and through a damping diode **57** by-passed by a capacitor **58**. The collector of transistor **53** is also connected through a high-frequency choke **60** and a grounded feed-through capacitor **61** to a tap **62** on a primary winding **63** wound upon one leg of a first ferromagnetic core **64** which forms part of horizontal sweep transformer **46**. Tap **62** is by-passed to ground by capacitors **66** and **67** and is also connected through a diode **68** and a resistor **69** to a terminal **70** at which, in operation, a comparatively high, but yet low-voltage, appears. Resistor **69** also is by-passed to ground by a capacitor **71**. Connected between the lower end of winding **63** and ground is the series combination of another diode **74**, a resistor **75** and a capacitor **76**, with diode **74** by-passed by a capacitor **77**. Another direct-current potential, of a value somewhat higher than the normal B+ supply, is developed at a terminal **78** connected to the junction between resistor **75** and capacitor **76**.

For supplying operating DC power, the conventional low-voltage source B+ is connected through a resistor **80** to a tap **81** on winding **63** intermediate tap **62** and the lower end of that winding. The junction between resistor **80** and tap **81** is filtered to ground by a capacitor **83** and also is connected through a diode **84** and a resistor **85** to a point of supply of a comparatively low-voltage waveform utilized in a conventional manner by certain correction circuits in the television receiver. The upper or high-potential end of winding **63** is connected directly to one side of the horizontal deflection windings in yoke **31**, the other end of those windings being returned to ground.

In operation, a negative-going rectangular pulse is applied to the base of transistor **53**. When the latter conducts, the inductance in winding **63** causes the current to rise slowly so as to result in a sawtooth waveform. When transistor **53** is cut off by action of the applied pulse, magnetic energy stored in winding **63** causes its current to reverse direction and flow through damping diode **57**, also generating a voltage pulse across winding **63**. The current in diode **57** slowly decreases to zero, at which time transistor **53** again conducts and the cycle is repeated. Thus, the scanning waveform actually applied to the horizontal coils in deflection yoke **31** is a sawtooth current repeating at the standard horizontal deflection frequency of 15,750 hertz. By inductive coupling through core **64**, similar but lesser-amplitude sawtooth current waveforms are induced in a secondary winding **87** also wound on a leg of core **64.** Winding **87** is tapped intermediate its length to ground so as to produce both negative-and positive-going pulses at respective different taps along the length of winding **87.** As indicated, these different taps serve to provide the waveforms at different amplitudes and polarities as required for use in the different correction circuits as well as to return the above-mentioned compensation waveform to sawtooth shaper **49.**

Also included as a part of the overall structure of transformer **46** is a tertiary winding **89** which feeds output pulses to a voltage multiplier **90** which in this case specifically is a tripler that also functions as a full-wave rectifier. In itself, tripler **90** is of known form. Thus, multiplier **90** includes a plurality of charging capacitors **91** cross-coupled in a ladder array of diodes **92** so as to triple the voltage level of the output pulses while at the same time rectifying the output pulse energy so as to produce a unidirectional high voltage HV at the output of the tripler. The side of the first diode presented with the output pulses is coupled to ground through one of capacitors **91,** while the others of those capacitors are connected individually between the different respective junctions between the various diodes. In operation, the application of an exemplary 9-kilovolt output pulse to the input side of multiplier **90** results in the appearance of approximately 9 kilovolts at the junction between the first commonly connected pair of diodes, approximately 18 kilovolts at the common junction between the third and fourth diodes and approximately 27 kilovolts at the multiplier output terminal HV. That output terminal also is returned to ground through the series combination of a potentiometer **94,** another potentiometer **95** and a resistor **96.** From the tap on potentiometer **94,** the requisite focus potential for application to cathode-ray tube **25** is derived. In practice, potentiometer **94** serves as a bleeder resistor, while potentiometer **95** is accessible for manual adjustment of the focus potential.

Ignoring structure and components shown in FIG. **3** but not yet specifically described, the operation of the system depicted in FIG. **3** is known, as such. Such an arrangement has been commercially employed, for example, in the 25DC56 chassis manufactured by Zenith Radio Corporation of Chicago, Ill. in 1973. The overall function of the horizontal system is primarily to provide the scanning waveforms necessary to energize the horizontal coils in the deflection yoke while at the same time recovering energy produced inherently within the deflection coils, upon collapse of the magnetic field developed thereby at the beginning of each retrace interval, and thus during the time interval between the horizontal scanning pulses. That recovered energy produces the output pulses delivered by tertiary winding **89.** As already noted, transformer **46** also serves to develop various different correcting, gating and compensating waveforms as well as permitting the production of different lower voltages for use elsewhere in the television receiver circuitry.

Notwithstanding the similarity of operation to that of known circuitry already alluded to, the illustrated embodiment of transformer **46** includes additional features enabling the attainment of the objectives mentioned in the introduction. To that end, it will be observed that core **64** is shaped to define a closed magnetic circuit. Moreover, the magnetic characteristics of its material together with its dimensions are selected to insure against saturation of core **64** in response either to development of the sawtooth-shaped current waveforms or in the presence of the energy developed and fed back to core **64** as a result of magnetic field collapse in the yoke. Furthermore, tertiary winding **89** is wound upon a second ferromagnetic core **98** which bridges only a portion **99** of core **64.** Thus, it will be observed that core **98** together with portion **99** define a second closed magnetic circuit. In this case, however, the magnetic characteristics and dimensions of core **98** are selected so as to saturate in response to energy induced in core **98** as a result of the magnetic field collapse in the yoke. In common parlance, transformer **46** thus may be viewed as including a primary leg **100** upon which winding **63** is wound, a tertiary leg **101** upon which winding **89** is wound and portion **99** of core **64** which functions as a shunt leg between the other two legs. In a manner known, as such, dielectric-filled gaps **102** and **103** may be included respectively in each of legs **100** and **99** to assist in achieving the desired operating reluctances in those two legs.

A storage capacitor **105** is coupled across tertiary winding **89.** Its capacitance is selected to have a value that enables the current cycles in tertiary winding **89** to coincide with the current cycles in primary winding **63** sufficiently that collapse of the magnetic field in yoke **31** initiates or triggers a reversal of saturation in core **98.** At the same time, the core structure is designed to allow capacitor **105** to store sufficient extra energy to supply losses in the core and load.

Completing the circuitry, one end of winding **89** is connected to an input of multiplier **90,** while the other end of that winding is connected to ground. As specifically illustrated, capacitor **105** is a discrete component separate both from winding **89** and from the capacitance presented by multiplier **90.** In practice, however, the capacitance necessary may be obtained from either one or both of the stray capacitance in winding **89** and the input capacitance of multiplier **90.**

In operation, the action of the system including winding **89** and capacitor **105** is such as to feed output pulses to multiplier **90** which feature a wide, flat-topped shape that, in turn, enables charging of the capacitors in multiplier **90** during a significantly large portion of each retrace interval. A typical pulse, of width W, is depicted in FIG. **3.** Capacitor **105** is in itself a storage device which stores energy during each retrace interval and then delivers that energy back into the total network so as to make broad pulses available for supplying energy to the voltage multiplier. One primary result is the attainment of good quality high-voltage regulation. At the same time, the operation of saturable core **98** is such as to have essentially no effect upon the shape of the horizontal scanning pulse present in primary winding **63.** Viewed another way, the illustrated arrangement permits the employment of saturation in the operating characteristics of the tertiary winding so as to obtain desired nonlinear effect while at the same time operation in primary winding **63** is always of a linear characteristic.

Considering the mode of operation in more detail, it may be noted first that the flux waveform in winding **89** is of generally triangular shape, while that in winding **63** is of sawtooth shape. After retrace, and the attendant collapse of the magnetic field in the yoke, the flux level in winding **63** is a maximum; the core under winding **89** would then be saturated except that the charge on capacitor **105** cannot change by reason of the high value of inductance in its discharge path. Consequently, the flux winding **89** increases in a generally sawtooth manner, while the balance of the flux goes into shunt leg **99**. The rate of increase of flux in winding **89** is determined essentially only by core **98** and capacitor **105** as a result of which the voltage induced across winding **89**, and hence the charge on capacitor **105**, is constant and does not depend on the primary circuit including winding **63**. At approximately the middle of the cycle of current waveform, core **98** saturates and the inductance in winding **89** drops, affording capacitor **105** a discharge path. Because of saturation, the flux in core **98** can no longer increase, so that the induced voltage, produced by change in flux, falls to zero. In discharging through the now-low inductance of winding **89**, there is an overshoot and capacitor **105** is charged in the reverse direction. Core **98** then comes out of saturation and the inductance presented by winding **89** again becomes of a high value so that once more charge is locked into capacitor **105**. The flux level now drops slowly, holding the voltage across winding **89** until core **98** becomes saturated in the opposite direction at which time the cycle repeats.

Several further features preferably are included in the design of the system in order to optimize operation. In still more detail, then, transformer **46** is designed so that its primary magnetic circuit in core **64** is operating on the normal or linear B-H characteristic while the tertiary magnetic circuit including core **98** is allowed to operate into the saturated regions of its B-H characteristic. Shunt leg **99** both enables saturation of the tertiary magnetic circuit and prevents saturation of the primary circuit. That is, the shunt path provided by leg portion **99** completes the magnetic circuit for the primary winding while the tertiary is in saturation. That shunt path also serves to reduce the amount of tertiary flux that otherwise would link the primary magnetic circuit.

As already indicated, the magnetic reluctance of primary leg **100** and shunt leg **99** is determined in each case by the inclusion of air gaps **102** and **103**. On the other hand, the reluctance of tertiary leg **101** is determined by its length and cross-sectional area alone. In practice, the cross-sectional areas of all three legs are chosen so that only tertiary leg **101** is forced into saturation and caused to exhibit a large reluctance. Consequently, the flux coupling from the primary leg to the tertiary leg may become small without effecting flux coupling in the reverse direction. That is, when the tertiary leg reaches saturation, any additional increase in the primary flux must go through the shunt leg and this, in turn, increases the magnetomotive force that appears across the tertiary leg.

In addition to saturation of tertiary leg **101**, capacitor **105** serves to control the voltage-current phase relationship in the tertiary winding in order to obtain the desired waveform transformation. That is, use of the

capacitor causes the voltage to lag the current so that energy is stored in the capacitor. While the rate of charge accumulated in capacitor **105** will be low at small flux magnitudes, because the tertiary winding will then appear as a large inductance, when saturation is reached the tertiary inductance decreases substantially so that capacitor **105** accumulates charge rapidly. When that stored energy subsequently is released through tertiary winding **89**, this likewise decreases the flux in tertiary leg **101** and forces the latter out of saturation. As the inductance of winding **89** thus again becomes larger, it controls the rate at which the stored energy is returned to core **98**. AS already noted, the energy stored in capacitor **105** at core saturation is sufficient to force tertiary leg **101** again to enter saturation at the opposite flux extreme during the return of energy from the capacitor. Thus, the tertiary core is forced to traverse the hysteresis loop of its B-H characteristic curve.

In traversing the unsaturated region of that B-H curve, the change in voltage across tertiary winding **89** is small, since capacitor **105** discharges and charges through a comparatively large inductance as determined by the minimum value of tertiary reluctance. On the other hand, the change in voltage across winding **89** during the saturation interval is comparatively large, since at that time the capacitor is completing its discharge or charge through a small inductance as determined by the maximum value of the tertiary reluctance. Preferably, the parameters are selected so that there is one complete traversal of the hysteresis loop for each cycle of applied primary waveform in order to achieve maximum efficiency. Sufficient energy is exchanged between capacitor **105** and tertiary core **98** so as to maintain essentially equal levels of positive and negative core saturation. Consequently, symmetry of the output pulse waveform is obtained. In turn, the peak-to-peak voltage of the output pulses is substantially independent of the input voltage, since the flux-time relationship when the core is substantially saturated is dependent instead only on the B-H characteristic, the value of capacitor **105**, the core dimensions and the number of turns of winding **89**.

By design of the system as specified, the action of the storage capacitor together with the non-linear reluctance behavior in the tertiary path results in the development of output pulses having a waveform which is approximately square in shape and nearly independent of B+ low-voltage supply variations. In addition, it is desired to minimize distortion of the waveform in primary winding **63**. To that end, shunt leg **99** is designed, by means of the selection of its cross section and the size of gap **103**, to exhibit a reluctance much smaller than that of primary leg **100**. Consequently, the tertiary magnetic circuit flux path is primarily only through the shunt leg portion of core **64** since, as already indicated, the cross-sectional area of the shunt leg portion is sufficiently large to prevent its own saturation.

In accordance with conventional practice, the required core dimension can be determined from the reluctance requirements, the B-H characteristics of the core materials and the system operational specifications. The general reluctance relationships are that the tertiary leg must be saturated by the primary magnetomotive force acting on the system alone while the shunt and primary legs do not saturate. At the same time, the maximum coercive foce existing in the shunt and primary legs must be less than the coercive force of the core at saturation flux density, while the maximum coercive force of the tertiary leg must be greater than the coercive force of the core at saturation flux density. These conditions insure that the primary magnetomotive force drives the tertiary leg well into saturation. Preferably, the coupling of flux from the tertiary to the primary leg is made close to unity in order to maximize flux coupled to the unsaturated tertiary leg. Additionally, the net reluctance change of the primary circuit as between the saturated and unsaturated conditions in the tertiary leg is kept low so that the primary current does not increase substantially when the tertiary leg saturates. To that end, the magnitude of the reluctance presented by shunt leg **99** is minimized at the same time that the already-mentioned conditions still are met. Other constraints on the core dimensions are satisfied by meeting the requirement that the flux in the primary leg due to the tertiary magnetomotive force be a minimum while the cross-sectional areas of both the primary and shunt legs are large enough to prevent saturation.

Capacitor **105** is of a value sufficient to store energy in an amount to supply both the energy dissipated in tertiary core **98** and the energy demands of the cathode-ray tube load, including dissipation in multiplier **90** and in the other associated circuitry such as the illustrated focus control network. However, when the load is substantially increased, the stored energy in capacitor **105** becomes insufficient to cause the tertiary core hysteresis to be completely traversed when energy is returned from the capacitor to the tertiary winding. Consequently, the tertiary voltage then becomes much lower in amplitude as well as unsymmetrical, as a result of which the operation of the tertiary magnetic circuit ceases to function and no longer is able to supply the energy demands of the load. Such operational drop-out provides short-circuit protection for the system. Even under short-circuit load conditions imposed on tertiary winding **89**, the peak current in primary winding **63** does not increase substantially. This occurs because the short circuit of the tertiary winding produces a tertiary magnetomotive force and flux in opposition to that provided by the primary winding. As a result, most of the primary flux is returned to the primary circuit through the shunt leg and hence provides isolation between the tertiary load and the primary supply. That is, the system affords overload protection for the primary driving source.

It will be observed that the described cathode-ray tube high-voltage supply system serves to optimize high voltage regulation characteristics while yet maintaining simplicity of the horizontal deflection system and without requiring any significant design changes in the design of the television receiver itself. It produces a well defined square-shaped tertiary output pulse. The system exhibits minimum ringing during scanning intervals while at the same time producing a flat positive peak during retrace in order to produce a linear relationship between high voltage and current. In addition, the substantial breadth of the output pulses enables charging of the capacitors in multiplier **90** for a substantial portion of the time available. At the same time, the output impedance presented by tertiary winding **89** is very low as a result of the saturation so as to maximize the voltage transfer to multiplier **90** by reason of the resulting small charge time constant. The combination of the ferro-magnetic effect and the substantial degree of saturation in the tertiary core results in the presentation of a constant peak-to-peak voltage to multiplier **90**. Moreover, the high voltage regulation exhibited by the system is substantially independent of at least reasonably small B+ supply voltage variations.

While a particular embodiment of the present invention has been shown and described, it is apparent that changes and modifications may be made therein without departing from the invention in its broader aspects. The aim of the appended claims, therefore, is to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim:

1. In a cathode ray tube high-voltage supply system in which sawtooth-shaped current pulses are developed in a first transformer winding in order to produce a scanning waveform in a deflection yoke on said cathode ray tube, in which energy developed as a result of magnetic field collapse in said deflection yoke is utilized to produce high-voltage output pulses in a second winding and in which the load coupled to said second winding requires a broad generally-square pulse shape, the improvement comprising:

a first closed magnetic circuit non-saturating in response to development of said sawtooth-shaped pulses or in the presence of said energy and including a first ferromagnetic core upon which said first winding is wound;

a second closed magnetic circuit saturating in response to said energy and including only a portion of said first core together with a second ferromagnetic core upon which said second winding is wound;

and a capacitor, included in said load, coupled across said second winding and having a value enabling current cycles in said second winding to coincide with current cycles in said first winding sufficiently that said collapse initiates saturation reversal in said second core.

2. A system as defined in claim **1** in which said load includes a voltage multiplier having capacitance chargeable by said output pulses and in which the magnetization characteristic of said second core is selected to optimize charging of said capacitance after each appearance of said sawtooth-shaped pulses.

3. A system as defined in claim **1** in which said second core is proportioned magnetically to develop said output pulses for optimized application to said load while effecting minimal effect upon the shape of said sawtooth pulses.

4. A system as defined in claim **1** in which said capacitor is of a value to store energy from said output pulses in an amount sufficient to drive said second core into saturation during the return of energy from said capacitor in the intervals between said output pulses.

5. A system as defined in claim **1** in which the value of said capacitor and the magnetic characteristic of said second core are selected such that said second core exhibits one complete traversal of its hysteresis loop for each cycle of said sawtooth-shaped pulses.

6. A system as defined in claim **5** in which the amount of energy exchanged between said capacitor and said second core is sufficient to maintain the degree of peak saturation of said second core substantially the same both during said output pulses and in the interval therebetween.

7. A system as defined in claim 1 in which the magnetic reluctance of said portion is substantially smaller than that of the remainder of said first core, and the cross-sectional area of said portion is sufficiently large to prevent its saturation in response both to said developed energy and to energy exchange between said capacitor and said second core.

8. A system as defined in claim 1 in which said portion is unsaturated in response to energy in said system while said second core saturates in response to exchange of energy with said capacitor.

9. A system as defined in claim 1 in which the maximum coercive force existing in said first core is less than the coercive force of said second core at saturation flux density, and the maximum coercive force of said second core is greater than the coercive force of said first core at the saturation flux density.

10. A system as defined in claim 1 in which the value of said capacitor is sufficient to store energy from said output pulses in an amount ample to return to said second core energy equal to energy dissipated therein together with energy required by said load.

11. A system as defined in claim 1 in which said second core saturates at approximately the middle of the current cycle, following which saturation said capacitor discharges and then is charged in the reverse direction.

12. A system as defined in claim 1 in which said capacitor is alternately charged in opposing directions, and in which said second core alternately becomes saturated in reverse directions.

13. A system as defined in claim 1 in which said second winding exhibits a value of inductance, during unsaturation of said second case, sufficiently high to prevent any significant discharge of said capacitor into said second winding.

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