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RASTER DISTORTION CORRECTED DEFLECTION CIRCUIT

This invention relates to a deflection circuit in which the amplitude of a deflection current may be varied or modulated over a relatively wide range for correcting a raster distortion. Modulation of the deflection current amplitude may be desirable for purposes such as, for example, correction of outside and of inside east-west pincushion distortion.

Typically, the horizontal deflection circuit includes an output stage having a deflection switch, a horizontal deflection winding and a trace capacitance that supplies deflection current to the deflection winding during each trace interval. A first retrace capacitance is coupled across the deflection winding during the retrace interval to form a retrace resonant circuit. Energy is replenished during retrace via a flyback transformer.

A high beam current provided from a secondary winding of the flyback transformer, during display, for example, of each white horizontal strip of a crosshatch pattern, such as shown in FIGURE 5, represents a heavy load to the flyback transformer during retrace.

In some prior art circuits, the retrace resonant circuit is coupled via a relatively small output impedance, of an east-west control circuit, to the primary winding of the flyback transformer throughout retrace. In such prior art circuits, the retrace capacitance may be slightly discharged during retrace due to the aforementioned loading. This may result in a discharge current from the trace capacitance into the retrace capacitance through the deflection winding and a resulting slight drop of the voltage across the trace capacitance due to the white horizontal strips of the crosshatch pattern.

The charge of the trace capacitance is replenished during the retrace intervals associated with the scan lines that display the black picture portion underneath the white crosshatch stripes. This causes a small current in the opposite direction, at a low frequency, to flow through the deflection winding during

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the trace intervals. The charge and discharge current of the trace capacitance produces a small raster displacement and results in low frequency oscillations modulating the deflection winding trace current. This low frequency modulation may cause each vertical strip of the crosshatch pattern to have of a zig-zag shape, instead of a straight line shape. The zig-zag shape appears in a given vertical direction immediately below the intersection point with a horizontal strip. Such distortions occurring at such low frequency, sometimes referred to as "mouseteeth" distortions, are illustrated in the crosshatch pattern of FIGURE 5.

Thus, mouseteeth distortions appear, during and just after the times in which high beam current transients occur, because the deflection circuit, that represents a low impedance energy flywheel during retrace, supplies the transient increase in energy requirement of the ultor circuit. Thus, energy transferred from the deflection circuit to the ultor circuit may tend to cause variations in the deflection winding trace current. The nature of mouseteeth distortion and corresponding solutions are explained in U.S. Patents 4,429,257; 4,634,937; 4,780,648 and 4,794,307.

In a horizontal deflection circuit, embodying an aspect of the invention, a modulation switching current is formed by a bidirectional modulation switch during retrace. The modulation switch, coupled to the retrace resonant circuit that includes the first retrace capacitance, has a conduction time that is phase modulated during horizontal retrace in accordance with a vertical rate parabolic voltage. A second retrace capacitor is coupled in parallel with the modulation switch. The modulation switch is conductive during the trace interval and is turned-off at a controllable instant during retrace. The modulation switch forms, when conductive, a low impedance across the second retrace capacitor that clamps the voltage across the second retrace capacitor to zero. As a result, a controllable retrace pulse voltage having an amplitude that is

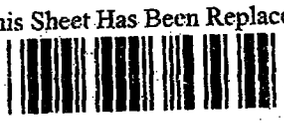
controllable and a width that is variable is developed across the second retrace capacitor when the modulation switch during a portion of retrace is nonconductive. The retrace voltage across the second retrace capacitor varies the magnitude of a retrace voltage that is developed across the first retrace capacitor and, in this way, provides the desired deflection winding current modulation so as to correct for outside and inside pincushion distortion.

Advantageously, by having the modulation switch conductive during only a portion of horizontal retrace, mouseteeth distortion is reduced. Mouseteeth distortion is reduced because, when the modulation switch is nonconductive during the other portion of horizontal retrace, the flyback transformer primary winding is coupled to the retrace resonant circuit via an impedance formed by the second retrace capacitor. Such impedance is high at low frequencies that are associated with mouseteeth distortion. Such frequencies are substantially lower than the retrace resonant frequency. By operating the modulation switch in the switching mode, power dissipation is, advantageously, reduced.

The retrace voltage in a secondary winding of the flyback transformer may be used to provide a synchronizing feedback signal that is used for providing timing information to a phase-control-circuit. The phase-control-circuit generates a control signal that synchronizes the horizontal deflection current to a horizontal synchronizing input signal.

In accordance with a feature of the invention, the second retrace capacitance causes the flyback transformer feedback signal to be maintained in phase with respect to the retrace voltage developed across the deflection winding. Thus, the feedback signal provides correct horizontal timing information of the horizontal deflection current throughout vertical scan. Had the retrace voltages in the flyback transformer and in the deflection winding not been maintained in phase during the entire vertical scan, a raster distortion resulting in a

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slightly parabolically bent raster in the vertical direction might have occurred.

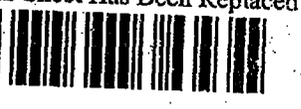
A television deflection apparatus embodying an aspect of the invention includes a source of a first input signal at a frequency that is related to a first deflection frequency and a retrace resonant circuit. The retrace resonant circuit includes a deflection winding and a first retrace capacitance. A deflection current is generated in the deflection winding and a first retrace pulse voltage is generated in the first retrace capacitance during a retrace interval of a given deflection cycle. A second retrace capacitance is coupled to the retrace resonant circuit for generating in the second retrace capacitance a second retrace pulse voltage during the retrace interval. A supply inductance coupled to a source of an input supply voltage couples the first and second retrace pulse voltages therethrough to a load circuit. A source of a modulation second input signal at a frequency that is related to a second deflection frequency is coupled to a switching arrangement. The switching arrangement varies, in accordance with the second input signal, a difference between a time when the second retrace pulse voltage is initiated and a time when the first retrace pulse voltage is initiated to produce a modulation of the deflection current. When the second retrace pulse voltage is generated, an impedance arrangement, that includes the second retrace capacitance, that is high at frequencies that are substantially lower than a retrace resonance frequency of the retrace resonant circuit, is interposed between the supply inductance and the retrace resonant circuit. The high impedance isolates the supply inductance from the retrace resonant circuit at the lower frequencies.

In the Drawing:

FIGURES 1a-1h illustrate idealized waveforms useful in explaining the circuit of FIGURE 2;

FIGURE 2 illustrates a deflection circuit, embodying an aspect of the invention, that includes outside pincushion distortion correction;

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FIGURES 3a-3b illustrate waveforms occurring during horizontal retrace that are useful in explaining the circuit of FIGURE 2;

FIGURE 4 illustrates additional waveforms that are useful in explaining the operation of the circuit of FIGURE 2;

FIGURE 5 illustrates a crosshatch pattern in which "mouseteeth" distortion is uncorrected;

FIGURES 6a-6d illustrate waveforms useful in explaining a current protection feature of the circuit of FIGURE 2;

FIGURE 7 illustrates a second embodiment of the invention that includes inside pincushion distortion correction; and

FIGURES 8a-8c illustrate waveforms associated with the circuit of FIGURE 7.

A horizontal deflection circuit 250 of FIGURE 2, embodying an aspect of the invention, provides horizontal deflection in, for example, an FS color cathode ray tube (CRT) type A66EAS00X01. Circuit 250 includes a switching transistor Q1 operating at a horizontal frequency f_H and an anti-parallel damper diode D_{Q1}, both being constructed as one integrated circuit. A retrace capacitance C1 is coupled in parallel with transistor Q1 and diode D_{Q1}. A deflection winding L_H is coupled in series with an S-shaping trace capacitance C_s to form a circuit branch that is coupled in parallel with each of transistor Q1, diode D_{Q1} and retrace capacitance C1 to form a retrace resonant circuit 100 during horizontal retrace.

A phase-control stage 101 that includes a horizontal oscillator and a phase detector, not shown in detail in FIGURES, is responsive to a horizontal synchronizing signal H_s. Signal H_s is derived from, for example, a video detector of a television receiver, not shown in the FIGURES. Stage 101 applies, via a transistor Q6, a drive voltage 101a to a primary winding T_{2a} of a driver transformer T2. Secondary winding T_{2b} of transformer T2 is coupled via a voltage divider, that

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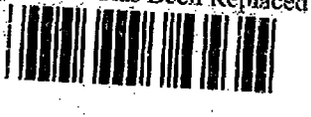
includes resistors R1 and R2, to the base-emitter junction of transistor Q1 for producing a base drive current i_b at the horizontal frequency f_H. A primary winding W_1 of a flyback transformer T1 is coupled between a source of a B+ voltage and the collector of transistor Q1. A secondary winding W_2 of transformer T1 is coupled to stage 101 to provide a feedback retrace signal H_r for generating drive signal 101a that synchronizes a horizontal deflection current i_2 in winding L_H to signal H_s.

A switched raster correction circuit 200, embodying a feature of the invention, includes an E-W control circuit 300 that controls the switching timing of a switching transistor Q2. Transistor Q2 is conductive throughout the trace interval and becomes nonconductive during a controllable instant within the retrace interval. The collector of transistor Q2 is coupled to a junction terminal 50 between the emitter of transistor Q1 and retrace capacitor C1. The emitter of transistor Q2 is coupled to ground via a small current sampling resistor R101. A damper diode D_{Q2} ,coupled in parallel with transistor Q2, is constructed with transistor Q2 as one integrated circuit. A second retrace capacitor C2 is coupled between the collector of transistor Q2 and ground. A retrace voltage V_r generated across a winding W_4 of transformer T1 provides a high voltage, used for generating an ultor voltage in an ultor power supply 556 that includes rectifying diodes, not shown in the FIGURES.

A first hypothetical example that is used for explanation purpose represents a first extreme operating condition in which transistor Q2 is maintained conductive throughout trace and retrace. In this case, deflection circuit 250 generates deflection current i_2 in a manner that is well known but without East-West correction. As explained later on, current i_2 is at a maximum peak-to-peak amplitude, in this case.

A second hypothetical example that is also used for explanation purposes, represents a second extreme operating condition in which switching transistor Q2 is in

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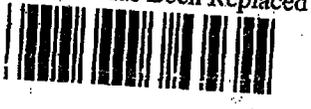


cutoff throughout an entire retrace interval. In the second example, during retrace, a pair of resonant circuits are formed. The first one, resonant circuit 100 of FIGURE 2, includes retrace capacitor C1, winding L_H and trace capacitor C_S. The second one includes flyback transformer winding W_1 and retrace capacitor C2 that are coupled in series. Considered separately, each of the pair of retrace resonant circuits is tuned to a frequency that is lower than a required nominal retrace frequency. The resonant circuits are coupled to form a combined resonant circuit. Therefore, the resulting common retrace frequency of the combined resonant circuit is higher than each of its constituents and is made equal to the required nominal retrace frequency that is, illustratively, 43 KHz in the PAL system.

As explained before, secondary winding W_2 of transformer T1 provides horizontal synchronizing retrace signal H_r. Each pulse of signal H_r represents the retrace interval in deflection winding L_H. Horizontal synchronizing signal H_r is coupled to phase-control-stage 101 for providing feedback synchronization information. The synchronization information contained in the pulses of signal H_r is indicative of the phase of current i_2 in deflection winding L_H. Signal H_r and horizontal sync pulses H_s are used to adjust the phase and the frequency of the horizontal oscillator output signal that is included in stage 101.

In the second hypothetical example, primary winding W_1 of transformer T1 is coupled to retrace resonant circuit 100 through a capacitive voltage divider that includes capacitors C1 and C2 to form the combined resonant circuit. The combined retrace resonant circuit enables proper synchronization without causing mouseteeth distortion. The advantages of forming such combined retrace resonant circuit are explained in detail in U.S. Patent 4,634,937 in the name of P.E. Haferl, entitled "EAST-WEST CORRECTION CIRCUIT".

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During trace, current i_1 in winding W_1 flows through transistor Q1 and through transistor Q2 to ground. During retrace, current i_1 that flows through capacitor C1 also flows through capacitor C2 as retrace current i_4 and causes a retrace voltage V_2 to be developed across retrace capacitor C2.

The amplitude of a retrace voltage V_1, developed across the series coupled capacitor C1 and C2 is stabilized by the B+ voltage that is regulated. Therefore, voltage V_1 is, advantageously, substantially unaffected by the East-West modulation. Retrace voltage V_4, developed across winding L_H and across capacitor C1, determines the amplitude of deflection current i_2. Retrace voltage V_4 is equal to retrace voltage V_1 minus retrace voltage V_2. Because current i_3 in transistor Q2 is zero during the second portion of retrace when transistor Q2 is nonconductive, retrace current i_1 flows substantially entirely as current i_4 through capacitor C2 and generates retrace voltage V_2. It follows that in the second hypothetical example in which transistor Q2 is nonconductive throughout retrace, voltage V_2 is at a maximum amplitude. Consequently, voltage V_4 amplitude is at a minimum and deflection current i_2 is also at a minimum in the second hypothetical example.

In accordance with an aspect of the invention, modulation of deflection current is obtained by a modulation of the turn-off instant of transistor Q2 during the first half of the retrace interval in a way that mouseteeth distortions are reduced. By selecting the value of capacitor C1 to be, for example, approximately twice that of capacitor C2, and the value of the inductance of winding W1 to be approximately twice that of winding L_H, the retrace frequency remains the same during both the first portion of retrace, when transistor Q2 is conductive, and during the second portion of retrace, when transistor Q2 is nonconductive. Consequently, the phase of voltage V_1 in winding W_1 relative to that of deflection current i_2 is unaffected by the conduction state of transistor Q2.

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Modulation of the turn-off instant is permissible because both the retrace time and a retrace voltage V_r developed from voltage V_1 in winding W_4 of transformer T1 are, advantageously, substantially unaffected by the state of conductance of transistor Q2, during retrace.

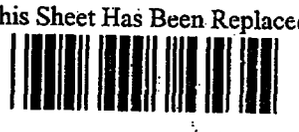
FIGURES 1a-1h illustrate idealized waveforms useful for explaining the operation of the circuit of FIGURE 2. Similar symbols and numerals in FIGURES 2 and in FIGURES 1a-1h indicate similar items or functions.

E-W control circuit 300 of FIGURE 2 generates a pulsed voltage V_3 which drives the base of transistor Q2. Voltage V_3 causes transistor Q2 to be conductive throughout the trace interval. During retrace, the falling edge of voltage V_3 is phase modulated in the range t_2-t_3 of FIGURE 1a. Thus, switching transistor Q2 of FIGURE 2 is conductive prior to time t_2 of FIGURE 1a and switched into cut-off after time t_2 at the phase modulated instant within the range t_2-t_3. When conductive, transistor Q2 clamps retrace voltage V_2 to zero and varies the instant when the generation of voltage v_2 occurs.

Current i_1 in winding W_1 of transformer T1 of FIGURE 2 flows into resonant circuit 100 that includes winding L_H and capacitor C1. From resonant circuit 100, current i_1 splits and forms current i_3 and current i_4 when transistor Q2 of FIGURE 2 is nonconductive. When transistor Q2 is turned-off, the decreasing current i_4 of FIGURE 1d charges capacitor C2 of FIGURE 2 until time t_4 of FIGURE 1d, occuring at the center of the retrace interval when currents i_1 and i_4 become zero. As a result, voltage V_2 of FIGURE 1e reaches its peak amplitude at the center of retrace. During the second half of retrace, negative current i_4 of FIGURE 1d, that becomes increasingly more negative, discharges capacitor C2 of FIGURE 2 until voltage V_2 becomes negative. When voltage V_2 becomes sufficiently negative, diode D_{Q2} starts conducting and clamps voltage V_2 to -0.6 voltage, the forward voltage of diode D_{Q2}.

The correction of outside pincushion distortion requires a higher amplitude of deflection current i_2 when

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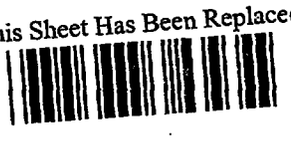


scanning lines at the center of the raster than at the top or bottom. At the top of the raster, transistor Q2 is turned off at time t_2 of FIGURE 1a, that is the earliest. Voltage V_2 of FIGURE 1e starts to increase after time t_2. After the center of retrace occurs, voltage V_2 decreases until it becomes zero at time t_6. Because transistor Q2 is turned off at the time t_2 at the top of the raster, the peak amplitude of voltage V_2 is at a maximum; consequently, the peak amplitude of voltage V_4 of FIGURE 1f is at a minimum. From the top toward the center of the raster, the turn-off time of transistor Q2, determined by the falling edge of voltage V_3 of FIGURE 1a, is increasingly delayed within interval $t_2 - t_3$. The result is a decreasing peak amplitude of voltage V_2 of FIGURE 2, an increasing peak amplitude of voltage V_4 and an increasing peak amplitude of deflection current i_2. At the center of the raster, voltage V_2 starts increasing at time t_3 of FIGURE 1e and becomes zero at time t_5 of each horizontal period. From the center toward the bottom of the raster, the turn-off time of transistor Q2 of FIGURE 2 is increasingly advanced from time t_3 to time t_2 of FIGURE 1a, resulting in an increasing voltage V_2 of FIGURE 2, a decreasing voltage V_4 and a decreasing deflection current i_2. Thus, deflection current i_2 is proportional to retrace voltage V_4 and inversely proportional to retrace voltage V_2 that is modulated in accordance with the turn-off instant of transistor Q2.

The falling edge of voltage V_3 of FIGURE 1a is phase modulated in a parabolic manner at a vertical rate to obtain the vertical rate envelopes shown in conjunction with waveforms 1e, 1f and 1h. Advantageously, the variation of the turn-off time of transistor Q2 of FIGURE 2 modulates also the time when voltage V_2 of FIGURE 1e becomes zero near the end of retrace.

In accordance with an inventive feature, the center of the retrace pulse waveform of voltage V_2 during horizontal retrace is maintained the same relative to the center of horizontal retrace time t_4 throughout vertical

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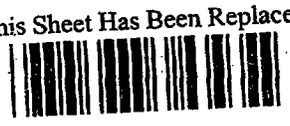
scan. Thus, voltages V_4 and V_2 of FIGURE 2 are maintained in phase with respect to voltage V_1. It follows that, advantageously, signal H_r is maintained in phase with deflection current i_2.

Signal H_r developed across winding W_2 provides phase information of the phase of deflection current i_2. Signal H_r is applied to stage 101 for synchronizing the horizontal oscillator of stage 101 to sync pulses H_s of the video signal. Because capacitor C2 couples winding W_1 to winding L_H to form a combined resonant circuit, the phase information of signal H_r is substantially identical to that of deflection current i_2. A further advantage provided by the switched operation of transistor Q2 is that inductive components are not required to be coupled in series with transistor Q2. Also, the switched operation of transistor Q2 results in low power dissipation in transistor Q2. Therefore, transistor Q2 may not require a heat sink. An additional advantage over other east-west circuits such as a conventional diode modulator is that deflection current i_2 does not flow through a damper diode during the second half of trace, resulting in lower deflection losses and lower asymmetric linearity error.

As explained before, during retrace, deflection resonant circuit 100 is coupled to flyback transformer T1 by capacitor C2 having a high impedance, after transistor Q2 becomes nonconductive. When transistor Q2 becomes nonconductive, the ultor voltage rectifying diodes, not shown, are conducting. The high impedance of capacitor C2 substantially isolates windings L_H and W_1 at frequencies associated with mouseteeth distortion that are substantially lower than the retrace frequency of resonant circuit 100 during retrace; thereby, raster distortions known as "mouseteeth" are prevented from occurring.

In accordance with a feature of the invention, junction terminal 50 between capacitors C1 and C2 is clamped to ground potential by transistor Q2 during the entire trace interval. Therefore, raster disturbances referred to as "Organ Pipes" do not appear. Organ Pipes

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type raster disturbances may occur if such clamping were not used as a result of oscillatory current or ringings in the flyback transformer primary current. Such ringings are suppressed because transistor Q1 is clamped to ground by transistor Q2 during the entire trace interval.

Advantageously, damper diodes D_{Q1} and D_{Q2} may be constructed with the corresponding transistor using the integrated circuit technology for further reducing the required discrete components count.

A protection diode D1 is coupled between the collector of transistor Q2 and a terminal W1a of primary winding W_1 of transformer T1. Diode D1 protects transistor Q2 from excessive peak voltage that may occur when power is initially turned on. Transistor Q2 is protected by diode D1 which limits voltage V_2 to a maximum of 350V. Transformer T2 has, preferably, 400V isolation capability between the primary and secondary windings.

A remote control receiver 201 generates an on/off control signal 201a that is coupled to an on/off transistor switch Q7 of a +12V regulator. When transistor Q7 is nonconductive, an output supply voltage +12V is generated that causes phase-control-stage 101 to be energized during power-up operation. When transistor Q7 is conductive, stage 101 is de-energized that causes stand-by mode operation. During a transition to the stand-by mode of operation, phase-control-stage 101 supplies base drive to the base of transistor Q6 to cause driver transistor Q6 of transformer T2 to be turned-off.

After, for example, the transition from normal or power-up operation to the stand-by mode operation there may still be energy stored in primary winding T_{2a} of transformer T2 of FIGURE 2. This energy may continue producing base current i_b in deflection transistor Q1 until a magnitude of voltage 101a across primary winding T_{2a} of transformer T2 decreases to zero. As a result, a final deflection cycle may be generated with an extended but undefined time duration that ends when transistor Q1 ceases

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to conduct. Consequently, currents i_1, i_2 and i_3 might increase excessively and destroy transistors Q1 and Q2.

To prevent such a possibility, on/off control signal 201a is coupled through a resistor R81 and a conductor 555 to the base electrode of a transistor Q5 that provides base drive to transistor Q2, causing transistor Q2 to turn off immediately after the power-on-to-standby transition. Since both transistors Q1 and Q2 are coupled in series, turning off transistor Q2 causes the current in both transistors to cease. Thus transistors Q1 and Q2 are protected. However, such fast shut-down arrangement may require a fast spot suppression circuit to prevent beam spot related damage to the CRT, not shown.

An alternative protection arrangement, which advantageously, may not require fast spot suppression is also shown in FIGURE 2. In such preferred arrangement, a feedback arrangement that includes a series arrangement of a diode D10 and a resistor R91 is coupled between the emitter of transistor Q2, as shown by the dashed line, and the base of transistor Q5, via conductor 555. When such feedback arrangement is used, the emitter of transistor Q2 is coupled to ground via current sampling resistor R101, causing current i_3 to be sampled across resistor R101. A resulting voltage V_{oc} developed across resistor R101 controls the base voltage of transistor Q5. When voltage V_{oc} across resistor R101 exceeds +1.8V, transistor Q5 is turned on by voltage V_{oc} and reduces the base drive of transistor Q2. Thus, current i_3 is limited to a peak of 1.8 ampere when, for example, resistor R101 equals 1 ohm.

The feedback provided by diode D10 and resistor R91, advantageously, protects both transistors Q1 and Q2 that are coupled in series during operation and, in particular, during the power-up-to-standby transition. It should be understood that such feedback arrangement may also be used together with, or instead of the arrangement in which signal 201a is coupled to the base of transistor Q5 that was explained before. When, for example, both arrangements are used together, current i_3 may become

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substantially reduced to, for example, zero for providing the required over-current protection or for providing on/off operation.

FIGURE 6a illustrates an envelope of a waveform of current i_3 of FIGURE 2 immediately after corresponding transitions between normal operation power-up mode and standby mode without the protection circuit, that would occur if conductor 555 were disconnected for disabling the operation of the protection circuit. Similarly, FIGURE 6b illustrates the envelope of the waveform of current i_3 of FIGURE 2 when conductor 555 is connected that enables the operation of the protection circuit. Note that current i_3 of FIGURE 6b is limited to the maximum of 1.8 amperes. Likewise, FIGURE 6c illustrates an envelope of collector current of Q1 when the protection circuit is disabled and FIGURE 6d illustrates the envelope of collector current of Q1 when the protection circuit is enabled. The operation of the protection circuit is also discussed in U.K. Patent Application 8805757, entitled PROTECTION ARRANGEMENT OF A DEFLECTION CIRCUIT, in the name of the same Applicant, filed 10 March 1988.

E-W control circuit 300 of FIGURE 2 includes a differential amplifier formed by transistors Q3 and Q4 and Darlington driver transistor Q5 which drives switching transistor Q2. The differential amplifier that includes transistors Q3 and Q4 compares a vertical parabola voltage V_6 to an exponentially shaped ramp portion V_{5a} of a voltage V_5 having a waveform that is shown in FIGURE 2. The crossover points of the compared voltages determines the timing of control voltage V_3 of FIGURE 1a.

To develop voltage V_5 of FIGURE 2, horizontal retrace pulses H_{w3} of FIGURE 2, developed in a winding W_3 of transformer T1, are coupled via a resistor R4 to a zener diode D3. A speed-up network that includes a capacitor C4, a resistor R5 and a diode D2 generates a gating pulse V_{D3} across diode D3 having a leading edge with a fast rise time. Faster leading edge, results, advantageously, in a larger dynamic range of E-W control circuit 300. Pulse V_{D3}

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across diode D3 is applied via resistors R6 and R7 to a capacitor C5 and to a resistor R9 for generating the exponentially shaped ramp portion V_{5a} of voltage V5. Pulsed voltage V5 that includes exponentially increasing top portion V_{5a} is applied to the base of transistor Q4. A vertical rate parabolic voltage V_p of FIGURE 2 that includes a superimposed sawtooth voltage is coupled from a DC blocking capacitor C_c of a conventional vertical deflection circuit 350 to the base of transistor Q3 via a capacitor C8, a resistor R20 and a resistor R19. Resistors R14, R15 and R16 provide dc bias to the base of transistor Q3. Voltage V_2 that is coupled via a resistor R13 to the base of transistor Q3 and to an integrating capacitor C6 provides a negative feedback, causing the vertical rate envelope of voltage V_2 to track parabolic voltage V_p that is developed in capacitor C_c.

A vertical sawtooth voltage V_{RS} developed across a sampling resistor R_s is coupled, via a resistor R10 and a resistor R9, to a capacitor C5 for developing a voltage V_7 having an exponential upramping portion at a peak amplitude that is determined by voltage V_{RS}. Voltage V_7 is coupled to the base of transistor Q4 of E-W control circuit 300. In this way, Voltage V_{RS} is also coupled via capacitor C_c to the base of transistor Q3. Because voltage V_{RS} is applied in a differential manner, voltage V_{RS} is prevented from substantially affecting the switching operation of transistors Q3 and Q4. A vertical parabola voltage V_6 developed at the base of transistor Q3 is compared to horizontal ramp voltage V_5. The crossover points of voltages V_5 and V_6 determine the timing of the leading and trailing edges of voltage V_3, as indicated before.

Exponentially shaped ramp portion V_{5a} of voltage V_5 linearizes the east-west raster correction or modulator circuit 200 by compensating for the decreasing level of current i_1 of FIGURE 1b, during retrace. Linearization occurs because a small amount of modulation of voltage V_3 near time t_2 of FIGURE 1a results in a higher amplitude modulation of voltage V_2 of FIGURE 1e than the same amount

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of modulation of voltage V_3 near time t_3 of FIGURE 1a. This is so because the amplitude of each of currents i_1 and i_4 of FIGURES 1b and 1d, respectively, is higher at time t_2 than at time t_3 and because voltage V_2 is proportional to the value of $\int i_4 . dt$. The exponentially shaped ramp voltage V_5 is steeper near time t_2 than at time t_3 of FIGURE 1g. Consequently, for a given voltage variation at the base of transistor Q3, the the modulation of voltage V_3 is smaller around time t_2 than around time t_3. Thus the exponentially shaped ramp portion V_{5a} of voltage V_5 linearizes the operation of E-W raster correction circuit 200. Resistor R15 raises the dc average of voltage V_5. Compensation of picture width variations as a function of beam current, that may be referred to as anti-breathing, may be applied via the base of transistor Q3.

FIGURES 3a-3b and 4 illustrate waveforms obtained in operating horizontal deflection circuit 250 of FIGURE 2. Similar symbols and numerals in FIGURES 1a-1h, 2, 3a-3b and 4 indicate similar items or functions. Advantageously, voltage V_1 of FIGURE 3a and current i_1 are substantially unmodulated. Between time t_2 and t_3 of FIGURE 3b transistor Q2 of FIGURE 2 is switched to cutoff. Diode D_{Q2} starts conducting between time t_5 and t_6 of FIGURE 3b. Advantageously, voltage V_2 of FIGURE 3b is centered around the center of voltage V_1 of FIGURE 3a. When voltage V_2 of FIGURE 3b is generated, current i_3 of FIGURE 3b is zero. Note that deflection current i_2 of FIGURE 4 is modulated to provide outside pincushion distortion correction.

Transistor Q5 of FIGURE 2, having a base that is coupled to the junction of a load resistor R12 and a collector of transistor Q3, applies a base drive to transistor Q2 from a load resistor R17 that is coupled to the collector of transistor Q5. The collector of transistor Q5 is coupled via a parallel arrangement of a capacitor C7 and a resistor R18 for generating a fast transition of a falling edge portion of voltage V_3 to obtain a fast turn-off of transistor Q2. The fast turn-off allows interrupting current i_3 immediately after time t_1 of

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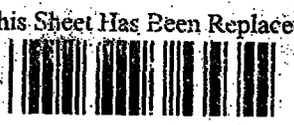


FIGURE 1c and allows using the full modulation range between time t_1 and t_4. Illustratively, the turn-off delay of transistor Q2 of FIGURE 2 is less than 1 microsecond. The use of a MOSFET in place of Q2 may further reduce the turn-off delay. The fast turn-off feature may be desirable in a situation that requires a deflection current at, for example, a higher frequency such as $2xf_H$.

FIGURE 7 illustrates a horizontal deflection circuit 250' that is similar to circuit 250 of FIGURE 2 and that is used for providing horizontal scanning in, for example, a Philips 45AX Picture tube, not shown. Similar numbers and symbols in FIGURES 7 and 2 indicate similar items or functions. However, circuit 250' of FIGURE 7 provides, in addition to outside pincushion correction that is provided as explained before with respect to FIGURE 2, also inside pincushion correction. Inside pincushion correction is obtained by the operation of a resonance circuit 60 that includes an inductor L1, a capacitor C'_S and that is coupled to a resistor R22. An inside pincushion correction modulation current i_5, modulated by voltage V_2, flows through trace capacitor C_S and through transistor Q2. Current i_5 modulates the trace voltage across capacitor C_S. The amount of inside correction may be adjusted by adjusting the value of inductor L1. This adjustment, however, is not critical, and a fixed coil of, for example, 2.2mH may be used. The required value of capacitor C2 of FIGURE 7 is greater than that in the circuit of FIGURE 2 because inductor L1 of FIGURE 7 is coupled in parallel with winding W_1 of transformer T1 during retrace. The manner by which a current such as current i_5 is modulated to provide inside pincushion correction is described in more detail in U.S. Patent No. 4,719,392, entitled RASTER CORRECTION CIRCUIT, in the name of P.E. Haferl.

FIGURES 8a-8c illustrate waveforms obtained during operation of circuit 250' of FIGURE 7. Similar numerals and symbols in FIGURES 8a-8c and 7 illustrate similar items or functions. Note that current i_3 of FIGURE

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8b is anti-"S"-shaped during trace, as a result of current i_5 of FIGURE 7. Without inside pincushion correction, current i_3 would have basically increased in a linear manner, as ideally shown in FIGURE 1c. Advantageously, transistor Q2 of FIGURE 7 also provides a current path for current i_5, during trace. Note that both currents i_5 of FIGURE 8a and current i_3 of FIGURE 8b are modulated to provide inside pincushion distortion correction.

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WHAT IS CLAIMED:

1. A television deflection apparatus, comprising:

a source of a first input signal at a frequency that is related to a first deflection frequency;

a retrace resonant circuit, including a deflection winding and a first retrace capacitance;

first switching means responsive to said first input signal and coupled to said retrace resonant circuit for generating a deflection current in said deflection winding and a first retrace pulse voltage in said first retrace capacitance during a retrace interval of a given deflection cycle;

a second retrace capacitance coupled to said retrace resonant circuit for generating in said second retrace capacitance a second retrace pulse voltage during said retrace interval;

a source of an input supply voltage;

a load circuit;

a supply inductance coupled to said source of input supply voltage and to said first switching means for coupling said first and second retrace pulse voltages therethrough to said load circuit and for replenishing energy losses in said retrace resonant circuit during said retrace interval; and

a source of a modulation second input signal; characterized by

second switching means (Q2) responsive to said first (101a) and second (V_3) input signals and coupled to said second retrace capacitance (C_2) for varying, in accordance with said second input signal (V_3), a time difference between initiation of said second retrace pulse voltage (V_2) and initiation of said first retrace pulse voltage (V_1) to produce a modulation of said deflection current (i_2) such that when said second retrace pulse voltage (V_2) is generated, an impedance arrangement is interposed between said supply inductance (W_1) and said retrace resonant circuit (100), said impedance arrangement

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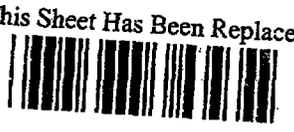
including said second retrace capacitance (C_2) and exhibiting a high impedance at frequencies that are substantially lower than a retrace resonance frequency of said retrace resonant circuit (100) for isolating said supply inductance (W_1) from said retrace resonant circuit (100) at said lower frequencies.

2. An apparatus according to Claim 1 characterized in that said second switching means (Q2) produces a variation of a pulse width of said second retrace pulse voltage (V_2) in accordance with said second input signal (V_3) such that a phase difference between corresponding predetermined portions of said first (V_1) and second (V_2) retrace pulse voltages remains substantially constant when said pulse width of said second retrace pulse voltage (V_2) varies for maintaining a third retrace pulse voltage (Hr), generated in said supply inductance (W_1), in correct synchronization with said deflection current (i_2) when said pulse width of said second retrace pulse voltage (V_2) varies.

3. An apparatus according to Claim 1 characterized in that said second switching means (Q2) operates in a conductive state during a first portion of said first retrace pulse voltage (V_1) for applying a low impedance across said second retrace capacitance (C_2) that delays the generation of said second retrace pulse voltage (V_2) and wherein said second switching means (Q2) operates in a nonconductive state for removing said low impedance to enable the generation of said second retrace pulse voltage (V_2) during a second portion of said first retrace pulse voltage (V_1).

4. An apparatus according to Claim 3 characterized in that said second switching means (Q2) is conductive until said first portion of said first retrace pulse voltage (V_1) having a length that varies in accordance with said second input signal (V_3) has elapsed to form a low impedance between a pair of terminals of said second retrace capacitance (C_2) during said first portion for preventing the generation of said second retrace pulse

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voltage (V_2), in accordance with said second input signal (V_3), as long as said second switching means (Q2) is conductive and wherein said second switching means (Q2) is nonconductive following said first portion for enabling the generation of said second retrace pulse voltage (V_2).

5. An apparatus according to Claim 1 characterized in that said supply inductance (W_1) comprises a winding of a flyback transformer (T_1) that is coupled through said second retrace capacitance (C_2) to said retrace resonant circuit (100) when said second switching means (Q2) is nonconductive and that is coupled through said second switching means (Q2) when said second switching means (Q2) is conductive to form a combined retrace resonant circuit having a resonance frequency that is substantially unchanged when said second switching means (Q2) is conductive and when it is nonconductive.

6. An apparatus according to Claim 1 characterized in that said second switching means (Q2) is coupled in series with said first switching means (Q1) during a portion of said given deflection cycle and in parallel with said second retrace capacitance (C_2) and wherein said second retrace capacitance (C_2) is coupled to a first junction terminal (50) between said first (Q1) and second (Q2) switching means and in series with said first retrace capacitance (C_1).

7. An apparatus according to Claim 1 characterized by a trace capacitance (C_S) that is coupled to said deflection winding (L_H) to form a first trace resonant circuit during a trace interval of said deflection cycle and a second trace resonant circuit (60) that is coupled to said trace capacitance (C_S) to provide an inside pincushion distortion correction wherein said second retrace pulse voltage (V_2), developed in said second retrace capacitance (C_2) when said second switching means (Q2) is nonconductive, generates an inside pincushion distortion correction modulation current in said second trace resonant circuit (60) that is modulated in accordance with said second retrace pulse voltage (V_2).

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* C L M S *

8. An apparatus according to Claim 1 characterized by means coupled to said retrace resonant circuit (100) for generating, during a horizontal retrace interval, a substantially square wave pulse (V_5) having an exponentially shaped top portion, said square wave pulse being coupled to a first input terminal (base of Q4) of a differential amplifier (Q3,Q4) of an East-West raster correction control circuit (300), a second input terminal (base of Q3) of said amplifier being responsive to a signal (V_6) at a vertical rate, for producing, at an output terminal (collector of Q3) of said differential amplifier, a modulation signal that is coupled to a control terminal (base) of said second switching means (Q2) having a phase that varies in accordance with said vertical rate signal (V_6), wherein said top portion of said square wave pulse voltage (V_5) varies in a manner that improves the linearity of said East-West raster correction control circuit (300) with respect to variations of said vertical rate signal (V_6).

9. A deflection apparatus with raster distortion correction, comprising:

a source of a first input signal at a frequency that is related to a horizontal deflection frequency;

a retrace resonant circuit including a deflection winding and a first retrace capacitance;

a first transistor switch responsive to said first input signal and coupled to said retrace resonant circuit for generating a horizontal deflection current in said deflection winding and a first retrace pulse voltage in said first retrace capacitance;

a second retrace capacitance coupled in series with said retrace resonant circuit for generating in said second retrace capacitance a second retrace pulse voltage;

a source of a second input signal at a frequency that is related to a vertical deflection frequency;

means responsive to said first and second input signals for generating a control signal at a horizontal

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frequency having a phase that varies in accordance with said vertical deflection frequency; characterized by

a second switch (Q2) coupled to said first transistor switch (Q1) such that during a portion of a given cycle of said deflection current (i_2) that occurs during a trace interval said first transistor switch (Q1) and said second switch (Q2) are coupled in series, said second switch (Q2) being responsive to said control signal (V_3) and coupled to said second retrace capacitance (C_2) for producing a variation of a time when said second retrace pulse voltage (V_2) is initiated relative to a time when said first retrace pulse voltage (V_1) is initiated while maintaining substantially constant a phase difference between the two retrace pulse voltages.

10. An apparatus according to Claim 9 characterized in that a center point between said time when said second retrace pulse voltage (V_2) is initiated and a time when said second retrace pulse voltage (V_2) is terminated remains substantially in phase with said first retrace pulse voltage (V_1).

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