

May 13, 1969

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3,444,422

CIRCUIT ARRANGEMENT FOR CORRECTING THE PIN-CUSHION DISTORTION

UPON DEFLECTION OF AN ELECTRON BEAM IN A DISPLAY TUBE

Filed Oct. 28, 1965

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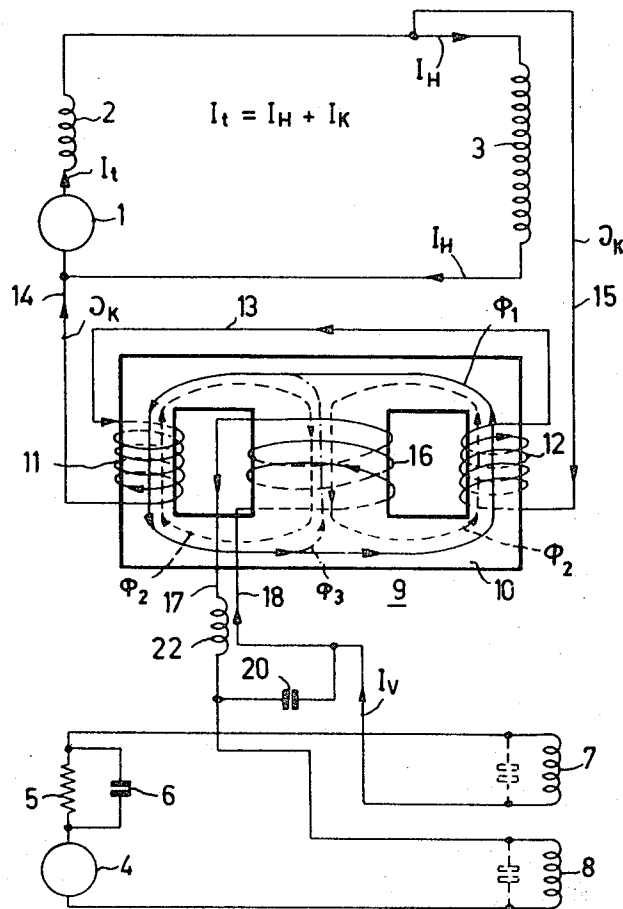


FIG. 1

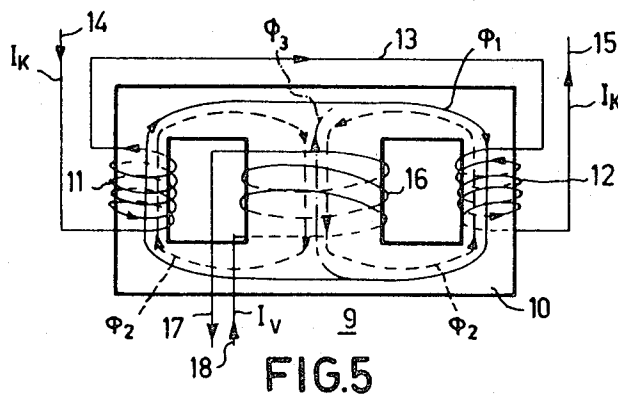


FIG. 5

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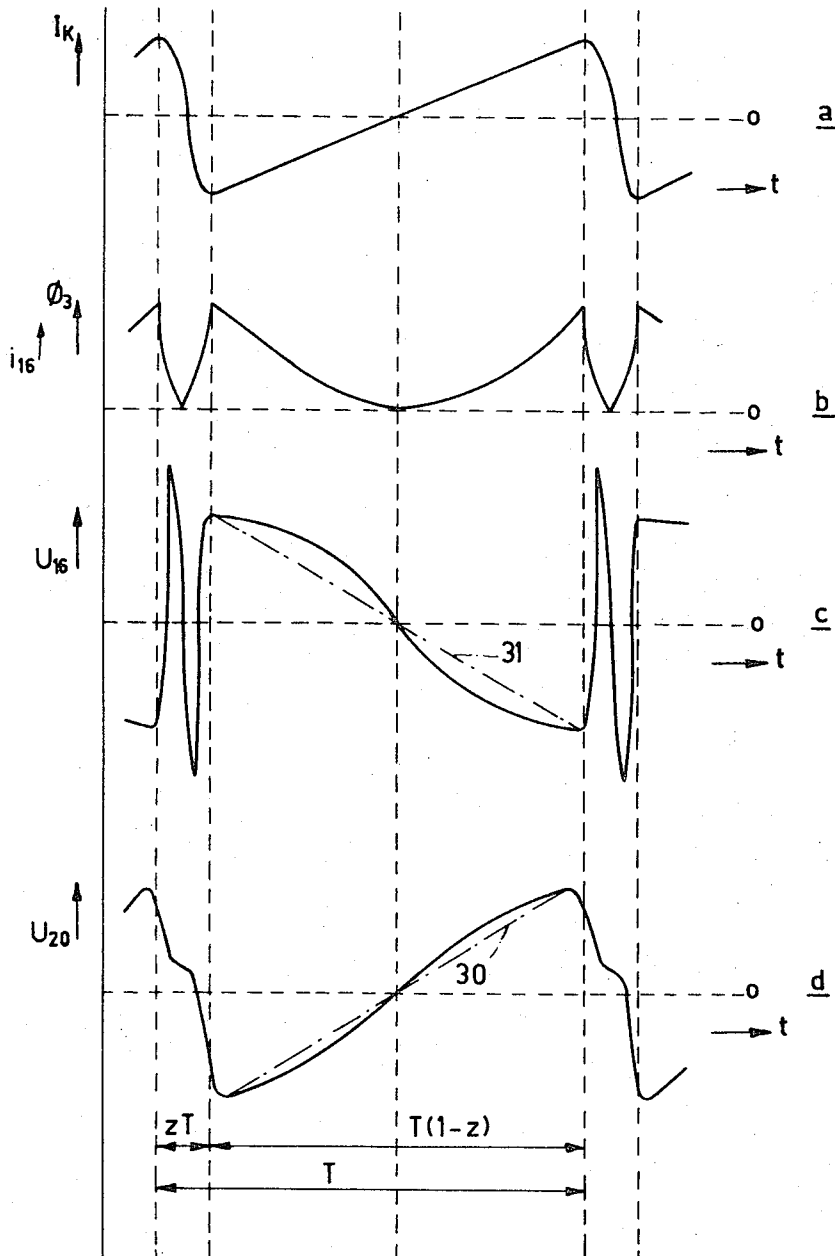


FIG.2

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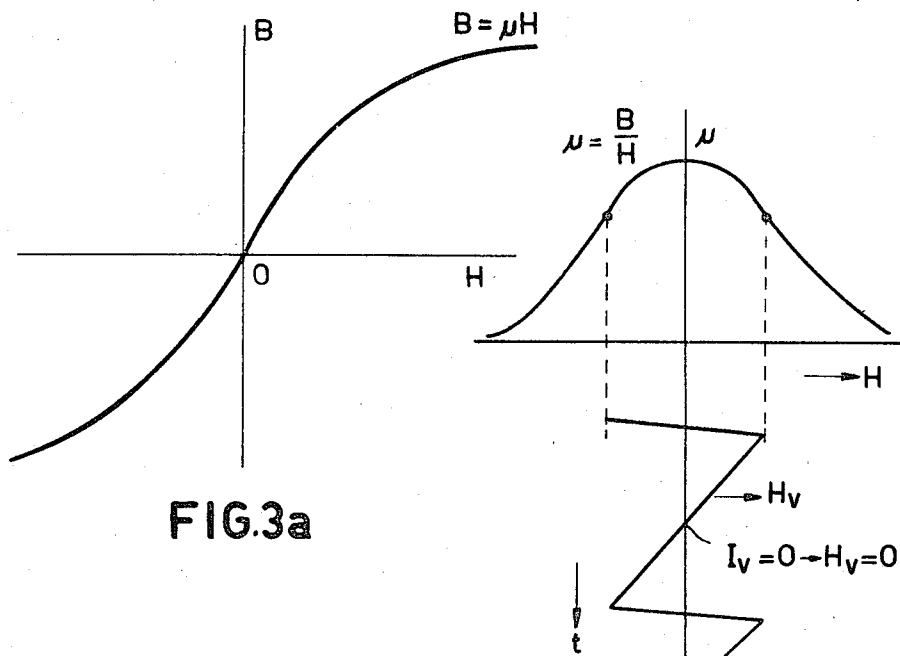


FIG. 3a

FIG. 3b

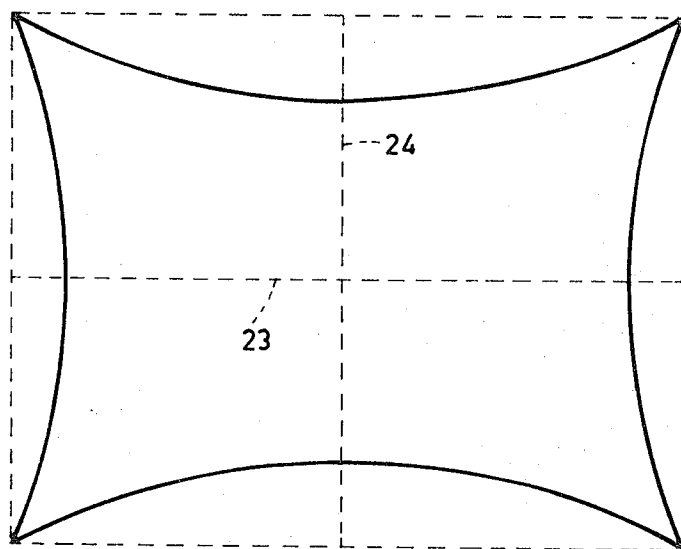


FIG. 4

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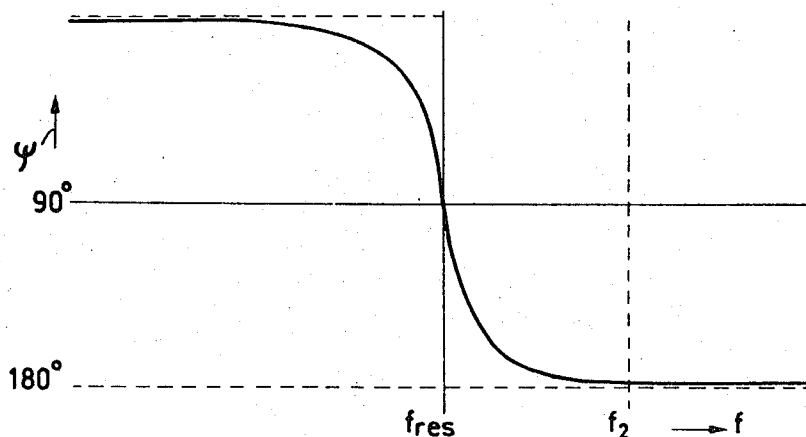


FIG. 6

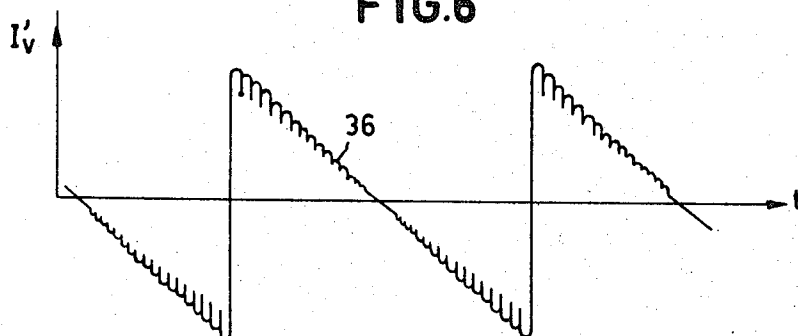


FIG. 7

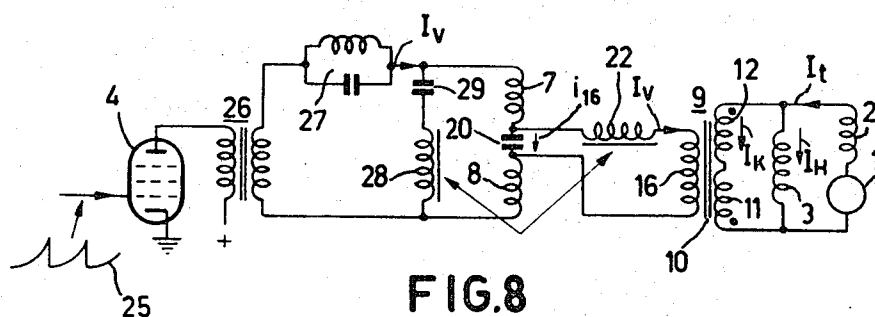


FIG. 8

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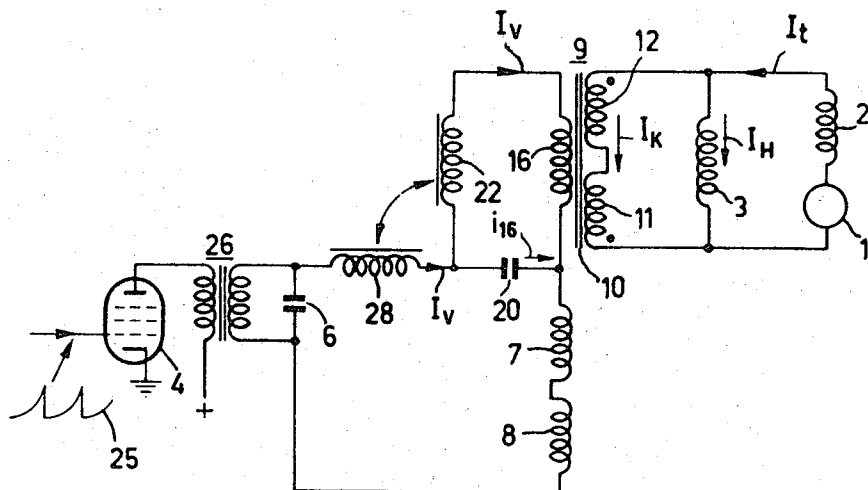


FIG. 9

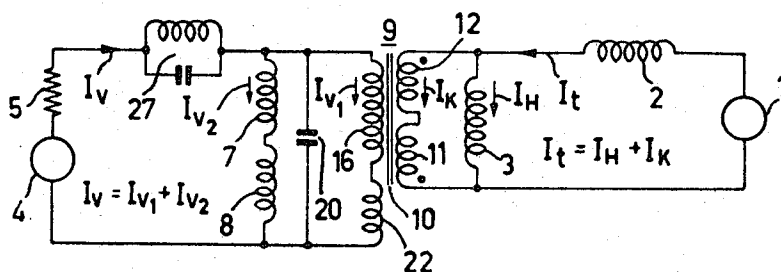


FIG. 10

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CIRCUIT ARRANGEMENT FOR CORRECTING THE PIN-CUSHION DISTORTION UPON DEFLECTION OF AN ELECTRON BEAM IN A DISPLAY TUBE

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Int. Cl. H01j 29/76

U.S. Cl. 315—24

16 Claims

ABSTRACT OF THE DISCLOSURE

A pincushion correction system for a television deflection system employs a transductor having first and second windings wound on a saturable core. The first winding is connected in parallel with the horizontal deflection coil and the second winding is connected in series with the vertical deflection coil and the frame deflection generator. The frame deflection current flowing in the second winding varies the inductance of the first winding so as to correct the side-to-side pincushion distortion. A capacitor and an inductor are connected in parallel with the second winding to form an LC resonant circuit that phase shifts the induced voltage of horizontal frequency in said second winding approximately 180 degrees. The phase shifted voltage is applied to the vertical deflection coil which has a relatively large inductance so that the applied voltage is integrated to correct the top-to-bottom pincushion distortion.

This invention relates to a television deflection circuit and more particularly to means for correcting the pincushion distortion of an electron beam deflected in two relatively perpendicular directions. In general, a deflection circuit of this type comprises a first deflection coil for deflecting the beam in a first direction at a comparatively high frequency, preferably in the horizontal direction. A sawtooth current is supplied thereto from a first current source. A transductor is provided having first and second windings wound on a saturable core having a non-linear magnetic inductance B /magnetic field strength H curve. The first winding is connected in parallel with the first deflection coil. A second deflection coil is provided for deflecting the beam in a second direction, preferably in the vertical direction, at a frequency which is comparatively low relative to that of the first direction. A sawtooth current is supplied thereto from a second current source so that said current flows, at least in part, through the second winding on the transductor core.

A deflection circuit of the type described above is described in U.S. Patent 2,906,919. The so-called potentiometer principle is invariably used in this known arrangement, i.e., for correction of the pin-cushion distortion a winding wound on the transductor core is connected in parallel with the deflection coil proper. The assembly is connected to a current source which provides the sawtooth current for deflecting the electron beam in one direction. The inductance of the winding is varied by means of the sawtooth current which deflects the beam in the other direction. The correction of the vertical deflection is effected by the horizontal deflection whereby the horizontal lines are straightened, the so-called north-south-correction. The correction of the horizontal deflection is effected by the vertical deflection whereby the length of the scan in the horizontal direction is corrected, the so-called east-west correction.

The east-west correction is suitable for the potentiometer principle, but the north-south correction is not since the north-south correction requires that a current of comparatively low frequency be corrected in a much higher rhythm (namely in the rhythm of the comparatively high frequency of the other direction of deflection). Since the internal resistance of the second current source is substantially ohmic, a variation in inductance has substantially no effect upon the amplitude of the current provided by this second source, unless the inductance of the variable winding is given a high value. However, in the latter case unwanted phase shifts occur.

For this reason it has previously been suggested to carry out the east-west correction with the aid of a transductor and the north-south correction with the aid of a separate modulator tube or a separate transistor. However, this implies a separate modulator stage with associated circuit elements and this is naturally expensive. An object of the invention is therefore to carry out both the north-south correction and the east-west correction by means of a transductor.

For this purpose the circuit arrangement according to the invention is characterized in that it includes means by which the voltage of comparatively high frequency, induced in the second winding due to the non-linearity of the core material, may be phase-shifted by approximately 180° and applied to the second deflection coil. The inductance of the second deflection coil is chosen so that said high frequency voltage is integrated.

It should be noted that the invention is based upon the following recognition. When using a transductor a reaction which is undesirable per se occurs and this, as will be explained more fully hereinafter, results in that the existing pin-cushion distortion of the horizontal lines (i.e., the pin-cushion distortion in the north-south direction) even being emphasized. By means of the invention, this unwanted emphasis is not only avoided, but is modified in such a manner that the pin-cushion distortion in the north-south direction is corrected.

In order that the invention may be readily carried into effect, several possible embodiments thereof will now be described in detail, by way of example, with reference to the accompanying diagrammatic drawings, in which:

FIGURE 1 shows a first embodiment of a circuit arrangement according to the invention;

FIGURE 2 shows a curve illustrating signals which occur in the arrangement of FIGURE 1;

FIGURE 3a shows a possible magnetic inductance B /magnetic field strength H curve of the material used for the core of the transductor;

FIGURE 3b shows a permeability μ /magnetic field strength H curve which is derived from the curve of FIGURE 3a;

FIGURE 4 shows a possible pin-cushion distortion which may occur on the screen of a television display tube;

FIGURE 5 shows a transductor as already shown in FIGURE 1, but with another direction of the magnetic flux in the external limbs;

FIGURE 6 shows a phase characteristic of an LC circuit as used for changing the unwanted reaction to a wanted correction signal;

FIGURE 7 shows the sawtooth current of comparatively low frequency together with the correction currents of comparatively high frequency superimposed on it for suppressing the pin-cushion distortion in the north-south direction;

FIGURE 8 shows a second embodiment of a circuit arrangement according to the invention;

FIGURE 9 shows a third, and

FIGURE 10 shows a fourth embodiment thereof.

In FIGURE 1, a first current source 1 provides the sawtooth current I_t for the horizontal deflection of the electron beam. An inductor 2 is regarded as being the internal impedance of the source 1, which approximates fairly well to the actual situation. The sawtooth current from the source 1 is supplied inter alia to a horizontal deflection coil 3 which may be mounted on the neck of a television display tube (not shown). For the European 625-line system, the repetition frequency f_L of the current provided by the source 1 is 15,625 c./s.

FIGURE 1 also shows a second current source 4 which provides the sawtooth current I_V for the vertical deflection of the electron beam. The internal resistance of the source 4 is represented by a resistor 5. As is well known, in a television receiver the internal resistance of the vertical output stage has an ohmic character. This is due to the fact that the repetition frequency for the vertical deflection is comparatively low (50 c./sec. for the European system) so that the vertical deflection coils have a substantially ohmic character at this frequency. It is therefore preferable to represent the internal resistance of the vertical output stage also as a substantially ohmic element.

The internal resistance 5 is imagined to be shunted by a capacitor 6. This capacitor, as will be explained hereinafter, must have a low impedance relative to the line frequency f_L since otherwise these line frequency signals can still exert an undesirable influence.

The vertical deflection current I_V is supplied to vertical deflection coils 7 and 8.

The deflection coils 3, 7 and 8 are usually combined in one. Said deflection coils do not cause deflection errors, which means that they are anastigmatic and free of coma. This is important, especially for colour television display tubes, since deflection errors result in colour errors.

However, such faultless deflection coils still cause pin-cushion distortion. The pin-cushion distortion is shown, for example, in FIGURE 4. According to the invention, it may be corrected by means of a single transductor 9, as shown in FIGURE 1.

The transductor preferably comprises a single core 10 having two external limbs on which windings 11 and 12 are wound in opposite directions. Said windings are connected in series with one another through a conductor 13 and connected in parallel with deflection coil 3 through conductors 14 and 15. Consequently, the current I_t from the source 1 is divided into currents I_K and I_H which flow through the windings 11 and 12, which are to be regarded as one winding, and the coil 3, respectively.

A second winding 16 is wound on the central limb of the transductor core 10 and connected through conductors 17 and 18 to a capacitor 20 and a coil 22.

The transductor 9 operates as follows. The line frequency current I_K shown in FIGURE 2a flows through the first winding 11, 12. The sawtooth current I_V of raster frequency flows through the second winding 16. The material of the core 10 has a magnetic inductance B /magnetic field strength H curve as shown in FIGURE 3a. A permeability μ /magnetic field strength H curve, as shown in FIGURE 3b, may be derived from said curve. In the two curves it has been assumed that the material of the core has substantially no hysteresis, which is a permissible approximation for the selected material of the core. If the core has a square loop B - H curve, it may be changed to the curve of FIGURE 3a by providing an air-gap or bevelling the external limbs by milling.

The current I_V which flows through the winding 16 results in a field variation H_V as shown in FIGURE 3b. Consequently, the greatly curved part of the μ - H curve is traversed, resulting in a more or less parabolic variation in the permeability μ . This variation in permeability results in a variation of the inductances $L_{11,12}$ of the windings 11 and 12 so that the amplitude of the sawtooth current I_H is varied parabolically with the raster frequency. If $I_V=0$, as is the case for line 23 in FIGURE 4, then $H_V=0$ and μ thus has a maximum value and the

inductance of windings 11 and 12 likewise have a maximum value. As a result, a minimum current I_K flows through the winding 11, 12. The source 1 having the internal impedance 2 provides a sawtooth deflection current I_t of constant amplitude. Therefore, the sum of the currents I_H and I_K is constant so that, if I_K is a minimum, I_H is a maximum. This is just what is required since, due to the pin-cushion distortion (FIGURE 4), I_H must be a maximum if $I_V=0$ and this is the case at the centre of the screen when viewed in the vertical direction (see the central horizontal line 23 in FIGURE 4).

The current I_V may be regarded substantially as a direct current relative to the line frequency signals since the frequency of 50 c./s. is so much lower than the frequency of 15,625 c./s. Therefore, a variation in the vertical deflection current I_V hardly occurs during a line cycle, i.e., the inductance $L_{11,12}$ each time is adjusted to another value as a function of I_V . As may appear from the foregoing, the current I_K is then a minimum and hence I_H a maximum if $I_V=0$. Conversely, if the current I_V is a maximum, the inductance $L_{11,12}$ is a minimum, and hence I_K is a maximum and I_H a minimum. However, the currents I_K and I_H remain substantially sawtooth-shaped but of variable amplitudes.

It may thus be assumed that the parallel connection of the series-combination of the windings 11 and 12 to the horizontal deflection coil 3 is the only circuit arrangement possible with pin-cushion distortion since even if—as is the case in the example of FIGURE 9—the winding 16 is connected in parallel with the vertical deflection coils 7 and 8, the vertical deflection current I_V is still a maximum at the end and the beginning of the vertical flyback period and zero during the middle of the period of a forward stroke (see line 23). It is thus impossible to inverse the phase in order to connect the series-combination of the windings 11 and 12 at will in series or in parallel with the horizontal deflection coil 3.

As has been shown above, I_K remains substantially sawtooth-shaped since the instantaneous value of I_V may be regarded substantially as constant during a line period T . Let it be assumed that I_V is maximum, or has a comparatively high value, and that I_K is a maximum at the beginning of a horizontal flyback period (the flyback period is indicated by zT in FIGURE 2). The current I_K which flows through the oppositely wound windings 11 and 12 results in a flux ϕ_1 in the material of the core. This flux, disregarding for the moment the action of the current I_V through the winding 16, flows only through the external limbs because in the case of symmetry of the two external limbs (the term "symmetry" is to be understood herein to mean that the degrees of saturation of the two limbs are the same, whereas the term "asymmetry" is to be understood to mean that the degrees of saturation of the two limbs are different) there is no reason for the flux ϕ_1 to flow through the central limb (since this would imply some leakage of the flux ϕ_1 which is negligible). The current I_V which flows through the winding 16 results in a flux of $2\phi_2$ as shown in broken lines in FIGURE 1. This flux is divided into two halves, each having an intensity of ϕ_2 which flows through the right-hand and left-hand limbs, respectively. As may be seen from FIGURE 1, the fluxes ϕ_1 and ϕ_2 support each other in the right-hand external limb and counteract each other in the left-hand external limb. Consequently, the right-hand external limb becomes more saturated and the left-hand external limb becomes less saturated, that is to say the magnetic reluctance of the right-hand limb increases (μ smaller) and that of the left-hand limb decreases (μ higher). The flux ϕ_1 produced by the current I_K thus has greater difficulty in flowing through the right-hand limb and tends to flow in part through the central limb (see the dot-and-dash curve indicated by ϕ_3 in FIGURE 1). This means that, due to the asymmetry of the external limbs, a flux $2\phi_2-\phi_3$ flows through the central limb. In other words, due to the action of I_K , the main flux ϕ_2 decreases on behalf of the flux indicated by ϕ_3 .

The current I_K reverses its direction during the flyback period so that the direction of the flux φ_1 produced by this current also reverses (FIGURE 5). However, the current I_V retains substantially the same value so that the flux φ_2 does not reverse its direction. From FIGURE 5 it follows that now the fluxes φ_1 and φ_2 support each other in the left-hand external limb and counteract each other in the right-hand limb. The left-hand limb becomes more saturated and the right-hand limb becomes less saturated. Consequently, the permeability in the left-hand limb decreases so that the magnetic reluctance in this limb increases. The flux φ_1 thus tends to avoid the left-hand limb and flows in part through the central limb (see the flux φ_3 , shown by the dot-and-dash curve in FIGURE 5).

Comparison of FIGURES 1 and 5 shows that the flux φ_3 which flows through the central limb due to the asymmetry in the saturation of the right-hand and left-hand limbs, has the same direction both at the beginning and at the end of the flyback period zT . In other words, the flux $\varphi_2 - \varphi_3$ through the central limb has its minimum value at both the beginning and the end of the flyback period since the flux φ_3 has its maximum value at these instants.

If $I_K = 0$ there is no difference in saturation between the left-hand and right-hand external limbs so that the flux φ_1 does not tend to flow through the central limb. Therefore, φ_3 is zero, that is to say the flux φ_3 through the central limb, caused by the current I_K , during a line period has the form shown in FIGURE 2b.

From FIGURES 1 and 5 it also appears that, irrespective of the direction of the current I_K , the flux φ_3 is invariably directed opposite to the flux φ_2 . Consequently, if the direction of I_V reverses, the flux φ_2 produced by it, and hence the flux φ_3 also reverses. If FIGURE 2b refers, for example, to a scan line above line 23 in FIGURE 4, the flux φ_3 is shifted in phase by 180° for a scan below line 23. This is fundamentally necessary, however, as will be explained hereinafter, since the correction current required must be shifted in phase by 180° above line 23 relative to that below line 23. This phase shift of 180° , which is caused due to the line 23 being passed during the scan, has nothing to do, however, with the fact mentioned hereinafter that φ_3 , and hence the current I_{16} produced by it, and the voltage U_{16} do not themselves have the current phase relationship for correcting the pin-cushion distortion.

It will be evident that the amplitude of φ_3 also depends upon the instantaneous value of I_V . The higher I_V , the higher φ_2 and the more saturated will be one of the external limbs. Consequently, the amplitude of the flux φ_3 driven through the central limb also increases.

A signal modulated in amplitude and phase is thus obtained by means of the transducer 9.

The above operation is possible only due to the non-linearity of the BH-curve shown in FIGURE 3a. The consequence of this non-linearity is that the decrease in the permeability μ as the result of the fluxes φ_1 and φ_2 which support each other in one external limb, proceeds differently from the increase in μ as the result of the fluxes φ_1 and φ_2 which counteract each other in the other external limb. Consequently, the variation in the inductance of the winding 11 proceeds differently from the variation in the inductance of the winding 12, which is necessary for bringing about the desired variation in the currents I_H and I_K . This is also necessary in order to ensure that the additional flux φ_3 flows through the central limb.

It is further to be noted that the windings 11 and 12 must preferably be connected in series. In the case shown in FIGURE 1, for example, the flux $2\varphi_2 - \varphi_3$ flows through the central limb. Thus a flux $\varphi_1 - \varphi_2 + \frac{1}{2}\varphi_3$ flows through the left-hand external limb and a flux $\varphi_1 + \varphi_2 - \frac{1}{2}\varphi_3$ flows through the right-hand external limb. The flux linking the winding 11 produces in it a counter EMF.

$$U_{11} = -\frac{d(\varphi_1 - \varphi_2 + \frac{1}{2}\varphi_3)}{dt}$$

On the other hand, the flux linking the winding 12 produces in it a counter EMF.

$$U_{12} = -\frac{d(\varphi_1 + \varphi_2 - \frac{1}{2}\varphi_3)}{dt}$$

From the above two equations it follows that, since φ_2 differs from $\frac{1}{2}\varphi_3$, U_{12} differs from U_{11} . Therefore, it is impossible for the windings 11 and 12 to be connected in parallel because in that case the difference in counter EMF could not arise. However, since the windings 11 and 12 are connected in series, the sum of $U_{11} + U_{12}$ is given by the current supplied but U_{11} and U_{12} can differ from each other. If desired, the windings 11 and 12 may be connected in parallel provided that a suitable impedance is interposed by which the difference between the voltages U_{11} and U_{12} may be neutralized.

Since $\varphi = L \cdot i$, the current I_{16} which flows through the winding 16 due to the current I_K has substantially the same form as the flux φ_3 , as is shown in FIGURE 2b (for a scan above line 23 in FIGURE 4).

The flux φ_3 induces in the winding 16 a voltage which is indicated by U_{16} . With the aid of the equation

$$U_{16} = \frac{d\varphi_3}{dt}$$

the form of the voltage U_{16} which is shown in FIGURE 2c may be derived from FIGURE 2b.

In the foregoing explanation of how the flux φ_3 and the resulting current I_{16} and the voltage U_{16} in the winding 16 arise, the capacitor 20 and the associated coil 22 have been completely disregarded.

It may be shown that the current I_{16} and the voltage U_{16} , unless special steps are taken, must be regarded as undesirable indeed. As may be seen from FIGURE 4, the horizontal lines on the upper and lower sides of the screen must be straightened. This may be achieved in that the vertical current I_V remains unchanged at the centre of the screen (dashed line 24 in FIGURE 4) but is decreased during a line period during the scan to the left and to the right of line 24. If one considers the current I_{16} shown in FIGURE 2b, it appears that this current, although having approximately the correct form, has a phase which is exactly opposite to the phase required for the correction of the pin-cushion distortion since I_{16} is a maximum at the beginning and the end of the flyback period. If the line frequency current I_{16} is added to the raster frequency current I_V , the current I_V increases instead of decreases to the right and to the left of line 24, that is to say the pin-cushion distortion is emphasized instead of corrected.

In principle, this undesirable effect may be counteracted by preventing the current I_{16} or the voltage U_{16} from reaching the vertical deflection coils 7 and 8 directly. Furthermore, means may be provided by which the available current I_{16} or the voltage U_{16} is shifted in phase by 180° , and then the phase-shifted signal is applied to the vertical deflection coils 7 and 8. Since the signal I_{16} shown in FIGURE 2b emphasizes the pin-cushion distortion, a 180° phase-shifted signal of the correct amplitude can eliminate said pin-cushion distortion.

One embodiment of a circuit arrangement thus designed is shown in FIGURE 8.

In FIGURE 8, the current source 4 having the internal resistance 5 has the form of a pentode tube. A control signal 25 is applied to the control grid of tube 4. The anode circuit of tube 4 includes a transformer 26. The vertical deflection coils 7 and 8 are connected to the secondary of transformer 26 by means of a blocking circuit 27 tuned to the repetition frequency f_L of the current source 1.

In the circuit diagram of FIGURE 8, the capacitor 20 has a very low impedance for line frequency signals and a very high impedance for raster frequency signals. The current I_V provided by the source 4 thus flows through the inductive part of the circuit 27, the deflection coils 7

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and 8 and the coil 22 and winding 16 connected in series therewith. The current I_{16} caused by the flux ϕ_3 , however, flows through the winding 16, the coil 22 and the capacitor 20 since the very low impedance of capacitor 20 relative to this line frequency current constitutes a short circuit. The coil 22 is magnetically coupled to a secondary winding 28 which is connected in series with a capacitor 29. This series combination is connected between the ends of the coils 7 and 8 which are remote from capacitor 20. The capacitor 29, too, has a low impedance for the line frequencies f_L and a high impedance for the raster frequency current I_V .

Since we invariably have

$$U = -L \frac{di}{dt}$$

the voltage induced in the secondary winding 28 is the derivative of the current I_{16} which flows through winding 22. The winding sense of winding 28 and its connection through capacitor 29 to the coils 7 and 8 is chosen so that the voltage across each of the deflection coils has exactly the correct phase.

As shown hereinbefore, the current I_{16} has substantially the correct form but the wrong phase. The voltage across winding 28 has the correct phase but is the derivative of the current I_{16} and must therefore be integrated again. This reintegration takes place in the deflection coils 7 and 8, which for this purpose require relatively large inductance values. The blocking circuit 27 ensure that the line frequency signals do not flow through the secondary winding of transformer 26. This is desirable primarily because the secondary winding of transformer 26 otherwise extracts an unnecessary load current from winding 28, which is to be regarded as a source. Secondly, this could imply unwanted action upon the source 4 by line frequency signals.

An arrangement which is somewhat simplified relative to FIGURE 8 is shown in FIGURE 9. The circuit for the current I_{16} , which is closed in itself, is formed similarly as in FIGURE 8 by means of the elements 16, 20 and 22 which have the same values in both arrangements. However, the winding 28 which is magnetically coupled to the winding 22 is now connected in series with the vertical deflection coils 7 and 8. Similar to the capacitor 29 of FIG. 8, the capacitor 6 has a low impedance relative to the line frequencies f_L and a high impedance relative to the raster frequency current I_V . Similarly to the arrangement of FIGURE 8, in the arrangement of FIGURE 9 the voltage of line frequency f_L induced in the winding 28 by the winding 22 appears across the coils 7 and 8. After integration thereof in said coils, the desired correction current for the north-south correction now also results.

An arrangement similar to those in FIGURES 8 and 9, which is simplified still further, is obtained if the desired phase displacement is effected in the manner illustrated in FIGURE 1.

It has been shown above that the current I_{16} must be shifted in phase by approximately 180° to obtain the desired correction signal. This phase displacement is effected by means of an LC-circuit in the example of FIGURE 1. Said circuit comprises capacitor 20, coil 22 and the inductance of transductor 9 as viewed in the direction from the conductors 17 and 18 to the winding 16. Said inductance, which is indicated by L_{16} for the sake of simplicity, comprises the inductance of the winding 16 and the stray inductance between the winding 16, on the one hand, and the windings 11 and 12 on the other. The resulting LC circuit is tuned to a resonant frequency f_{res} which is so much lower than the repetition frequency f_L of the sawtooth current from the source 1 that a voltage of the desired phase and amplitude appears across capacitor 20.

The voltage

$$U_{16} = -d\phi_3/dt$$

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has the waveform shown in FIGURE 2c. Since the current I_{16} has the wrong phase this is also true for the voltage U_{16} . Since the voltage U_{16} is a voltage which is induced in the winding 16, a source providing the voltage U_{16} may be imagined to be in series with the inductor L and the capacitor C of the above mentioned LC circuit. Since the L in the circuit invariably has a certain resistance R , the current i in the circuit comprising the elements 16, 22 and 20 may be written as:

$$i = \frac{U_{16}}{j\omega L + \frac{1}{j\omega C_{20}} + R}$$

where C_{20} is the capacitance of capacitor 20. The voltage U_{20} across capacitor 20 is in this case

$$U_{20} = \frac{i}{j\omega C_{20}} = \frac{U_{16}}{1 - \omega^2 LC_{20} + j\omega RC_{20}}$$

This expression may be written as:

$$U_{20} = \frac{U_{16}}{\{(1 - \omega^2 LC_{20})^2 + \omega^2 R^2 C_{20}^2\}^{1/2} e^{-i\psi}}$$

wherein

$$\psi = \arctan \frac{\omega RC_{20}}{1 - \omega^2 LC_{20}}$$

The value ψ given by the latter equation is plotted against frequency f in FIGURE 6, where $\omega = 2\pi f$.

For $\psi = 180^\circ$ a phase shift of exactly 180° exists between the induced voltage U_{16} and the voltage U_{20} across capacitor 20. This value for ψ only occurs, however, if $\omega^2 LC_{20} = \infty$ which is in practice not obtainable. A very satisfactory result is obtained, however, if $\psi = 170^\circ$.

Since

$$2\pi f_{res} = \omega_{res} = \frac{1}{\sqrt{LC_{20}}}$$

the resonance frequency f_{res} must be chosen relative to the repetition frequency f_L of the source 1 so that we have:

$$2\pi f_L = \omega_L > \omega_{res}$$

In other words:

$$\omega_L^2 LC_{20}$$

must exceed unity by so much that the phase angle ψ lies between 170° and 180° .

FIGURE 6 shows that the phase $\psi = 90^\circ$ occurs for the frequency f_{res} and that the desired value of ψ occurs for the frequency f_L . The wave form of the voltage U_{20} across capacitor 20 is shown in FIGURE 2d.

As in the embodiment of FIGURE 8, in the embodiment of FIGURE 1 the voltage U_{20} must also be integrated by the vertical deflection coils 7 and 8 before the desired correction current is obtained. This is possible because capacitor 6 constitutes a short-circuit relative to the line frequencies. Consequently, the ends of the coils 7 and 8 which are connected to the resistor 5 and the source 4, respectively, may be regarded as connected together relative to the line frequencies. If the capacitor voltage U_{20} is regarded as a source, it causes a voltage across the coils 7 and 8 so that the current I which flows through these coils is the integral of said voltage. The current I_V and the current obtained by integration of the voltage U_{20} are then automatically added together in the coils 7 and 8 so that the resulting current I_V has the desired wave form shown in FIGURE 7.

The condition $\psi \approx 170^\circ$ is fulfilled more easily as the resistance R is smaller. This first condition thus implies an optimum quality of the LC circuit. However, the quality of this circuit cannot be raised excessively since otherwise an unduly low voltage U_{20} is produced across capacitor 20 at the frequency f_L . It will be evident that the quality Q of the circuit must be chosen so that a favourable compromise between the two requirements is obtained.

It is true that the fundamental frequency of the signal U_{16} is favoured relative to the higher harmonics by a

high quality of the circuit and by the tuning of the said LC circuit, but it has been found in practice that the consequent distortion hardly influences the correction.

Since the voltage U_{20} must be integrated in the coils 7 and 8, and integration of a sawtooth voltage provides the desired parabolic current, the ideal voltage form for U_{20} is that shown by the dot-and-dash line 30 in FIGURE 2d. As may be seen the actual voltage hardly differs from the ideal wave form during the forward stroke period $T(1-z)$ as is shown by the curve in full line in FIGURE 2d.

It has even been found that the use of the LC circuit has a slightly correcting action since the voltage U_{16} differs comparatively more from the ideal form than does the voltage U_{20} (compare the dot-and-dash line 31 in FIGURE 2c, which shows the ideal voltage form, with the curve shown in full line in this figure).

This is presumably attributable to the fact that, due to the non-linearity of the material of the core 10, the higher harmonics in the voltage U_{16} are represented comparatively too strongly. This is corrected by the tuning of the LC circuit.

As explained hereinbefore, the value of the inductance L_{16} , as viewed in the direction from the conductors 17 and 18 to the winding 16, also plays a part in the LC circuit for the 180° phase shift of the voltage U_{16} . The inductance L_{16} is variable due to the variable permeability of the core 10. However, if the inductance of the coil 22 is given a high value relative to L_{16} , the tuning of the circuit is hardly influenced by variation of L_{16} . Furthermore, capacitor 20 may become smaller by raising the total inductance in the circuit so that the voltage U_{20} set up across capacitor 20 increases with the quality of the circuit unchanged.

However, such proportioning may be found without undue difficulty because of the variability of L_{16} , without using the coils 22, to obtain correct tuning.

In the embodiment of FIGURE 1, the winding 16, apart from the coil 22, is connected in series with the deflection coils 7 and 8. In this case the capacitor 6 must provide for short-circuiting the line frequency currents so that the voltage U_{20} becomes directly available to the deflection coils 7 and 8.

FIGURE 10 shows that it is possible for the winding 16, if desired in series with the coil 22, to be connected in parallel with the deflection coils 7 and 8. In this case a current I_{V2} flows through the coils 7 and 8 and a current I_{V1} flows through the winding 16 and the coil 22. Then $I_V = I_{V1} + I_{V2}$, where I_V is the current of raster frequency supplied by the source 4. The ohmic resistance in the circuit including the coils 7 and 8 and that in the circuit including the coil 22 and the winding 16 determine the magnitudes of the currents I_{V2} and I_{V1} , respectively. The source 4 must now actually provide a current I_V which is twice that in the circuit arrangement of FIGURE 1.

In the circuit arrangement of FIGURE 10, a voltage U_{16} is induced in the winding 16 in a manner similar to FIGURE 1. The voltage U_{16} is phase shifted by 180° by the LC circuit comprising the elements L_{16} , L_{22} and C_{20} so that a voltage U_{20} of the wave form shown in FIGURE 2d appears across capacitor 20. Since capacitor 20 is connected in parallel with the deflection coils 7 and 8, the voltage U_{20} is directly available to said deflection coils. After integration thereof in said coils the desired parabolic current for correction in the north-south direction again results.

As a matter of fact it is necessary to ensure similarly, as in the circuit arrangement of FIGURE 8, that the line frequency currents do not flow via the source 4. This is achieved by providing a blocking circuit 27.

It should be noted that the functions of the windings 11 and 12, which are connected in series, and of the winding 16, are interchangeable. For this purpose the connections to the conductors 14 and 15 may be exchanged

with those of the conductors 17 and 18 and vice versa. As a matter of fact, the number of ampere turns of the various windings must then be matched correspondingly.

In the latter case it is possible, in a similar manner as explained hereinbefore, that as a result of the non-linearity of the material of the core 10, the desired correction occurs in both the east-west direction and the north-south direction.

It should further be noted that it is preferable, in view of the manufacturing cost, to use a single core 10 for the transducer 9, but this is not strictly necessary. It is possible to use four C-cores which are arranged in pairs so as to obtain two closed magnetic circuits. The windings 11 and 12 are wound respectively on a limb of each of the pairs of C-cores. The windings 11 and 12 are then wound in the same manner and connected as in FIGURES 1 and 5, if one considers the core 10 to be divided into two pieces.

The winding 16 must be divided into two equal halves. One half is wound on the limb of one pair and the other half is wound in the same sense on the limb of the other pair.

The operation of the circuit arrangement having two pairs of cores is quite similar to that including a single core. In the case of two pairs of cores, the fluxes ϕ_1 and ϕ_2 support one another in the magnetic circuit of one pair and counteract one another in the other pair. Since the cores become saturated where the fluxes support one another, variation in inductance and induction of a voltage U_{16} again result, as is required for the desired east-west correction and north-south correction, respectively.

Although in the foregoing we have assumed a B-H curve (as shown in FIGURE 3a) having a continuous wave form, it is possible to use a core material having a square loop B-H curve. Two conditions may, in principle, be formed with this core material, namely a condition of comparatively high permeability and one of comparatively low permeability. The condition of low permeability is referred to as that in which the material has reached its saturation. However, in this case it cannot be said that one external limb of the transducer core 10 is gradually becoming saturated and it is necessary to reckon with a saturated or unsaturated condition of one of the two external limbs.

This does not make much difference for the so-called east-west pin-cushion correction because in this case the amplitude of the current I_K , and hence of the current I_H , may be varied in the desired manner by variation of the impedances.

However, a difference does exist for the north-south pin-cushion correction. Due to the external limbs becoming saturated or not saturated, the current I_{16} acquires a pulsatory character. The width of the pulses and their amplitudes then increase with increasing value of the vertical deflection current I_V (that is to say an absolute increase and hence from zero in the positive direction as well as from zero in the negative direction). The current I_{16} cannot therefore be said to have approximately the desired wave form for the north-south correction. The tuned circuit constituted by the winding 16, the coil 22 which is connected in series with it, and the capacitor 20 must therefore ensure, in addition to inverting the phase, that the voltage U_{20} across capacitor 20 acquires the desired form. In this case a more or less sinusoidal swinging is present in the said LC circuit. Also, due to the double excitation of said circuit (a pulse is produced both at the beginning and at the end of a stroke period, see also FIGURE 2b) one obtains approximately the correct form of voltage for U_{20} so that the voltage U_{20} , after being integrated in the vertical deflection coils 7 and 8, provides approximately the desired correction current even when using square loop material for the core. Even if such material is used the circuit arrangement of FIGURE 1 need not be modified and it is only necessary to vary slightly the proportioning of the winding 16, the coil 22 and the capacitor 20.

In conclusion, it is to be noted that, for the operation of transductor 9, it is not necessary that the currents I_K and I_V (I_V in FIGURES 1, 5 and 8 and I_{V1} in FIGURE 10) have the same values. The peak-to-peak value of the current I_K in the example of FIGURE 1 is approximately 20 ma., that is to say the current varies between -15 ma. and +15 ma. if $I_V=0$. For a peak-to-peak value of 600 ma. for the current I_V , that is to say for a variation between -300 ma. and +300 ma., the peak-to-peak value of the current I_K is approximately 250 ma., that is to say the current I_K varies in this case between -125 ma. and +125 ma.

A specification of the elements used in the circuit arrangement of FIGURE 1 for a core of rectangular material now follows.

The core 10 is an E.I. core from Messrs. Valvo of type VK 25,202 which is made of ferroxcube 306. The external limbs of this core have been bevelled by milling in a ratio 2:1 in order to obtain the desired BH curve.

The windings 11 and 12 each comprise 600 turns of lacquered copper wire of 0.15 mm. in diameter. The number of turns of the winding 16 is 100 and the wire used has a thickness of 0.25 mm. The ohmic resistance of the winding 16 is 1 ohm. The inductance of each of the vertical deflection coils 7 and 8 is 17 mh. and their ohmic resistance is 15 ohms. In fact, a compromise must be made between the requirement that the coils 7 and 8 can integrate the line frequency voltage U_{20} and the requirement that the load for the source 4 is substantially ohmic. These requirements imply respectively a high inductance and a high resistivity.

For a value of 39 nf. for capacitor 20, the maximum peak-to-peak value (that is the value at $I_V=\text{maximum}$) of the voltage U_{20} was approximately 200 volts. This voltage was measured in the absence of the coil 22. By providing the coil 22 it is possible to make the capacitor 20 smaller and hence increase the voltage U_{20} with the quality of the circuit unchanged. The resonance frequency f_{res} to which the LC circuit is tuned is 10 kc./s.

The inductance of the deflection coil 3 is 2.9 mh. and its resistance is 2.5 ohms. The internal impedance 2 of the source 1 is 1.7 mh.

What is claimed is:

1. A cathode ray tube deflection circuit for correcting pin-cushion distortion of an electron beam deflected in two relatively perpendicular directions, comprising a first deflection coil for deflecting said beam in a first direction at a comparatively high frequency, a first sawtooth current source coupled to said first coil, a transductor having a core that exhibits a non-linear magnetic B-H curve and first and second windings on said core, means connecting said first winding in parallel with said first deflection coil, a second deflection coil for deflecting the beam in a second direction at a frequency which is comparatively low relative to said high frequency, a second sawtooth current source coupled to said second deflection coil and to said second transductor winding so that at least a part of the sawtooth current flows through said second transductor winding, said second transductor winding having a voltage of said high frequency induced therein due to the non-linearity of said core material, phase shift means coupled to the second winding for shifting in phase said induced voltage by approximately 180° , and means for applying the phase shifted voltage to the second deflection coil, and said second deflection coil has a relatively large inductance so that it exhibits a reactive impedance at said high frequency that is large relative to its ohmic impedance thereby to produce integration of the voltage applied thereto.

2. A circuit as claimed in claim 1 wherein said phase shift means comprises a capacitor connected in parallel with the transductor second winding so as to form, together with the active inductance of the transductor, an LC circuit having a resonant frequency that is lower than

the repetition frequency of the first sawtooth current source whereby the voltage developed across the capacitor is phase-shifted by approximately 180° relative to the induced voltage in said second winding.

3. A circuit as claimed in claim 2 wherein the value of said resonant frequency is chosen so that the phase difference between the induced voltage and the voltage across the capacitor lies between 170° and 180° .

4. A circuit as claimed in claim 2 wherein said LC circuit further includes a coil having a constant inductance which is high relative to the inductance of the transductor.

5. A circuit as claimed in claim 2 wherein the second deflection coil is divided into two equal parts, means connecting the external ends thereof to the second current source and the internal ends thereof to the transductor second winding, said circuit further comprising a second capacitor having a low impedance at the repetition frequency of the first current source, and means connecting said second capacitor in shunt with said second current source.

6. A circuit as claimed in claim 1 further comprising, means connecting the transductor second winding in parallel circuit with the second deflection coil, a blocking circuit tuned to the repetition frequency of the first current source connected in series with said parallel circuit, and means connecting the series-combination of the parallel circuit and the blocking circuit to the second current source.

7. A circuit as claimed in claim 1 wherein the core of the transductor is made of a material that exhibits a square loop hysteresis curve, said material being controlled into a substantially unsaturated condition or a substantially saturated condition by the coaction of the currents in the first and second windings.

8. A circuit as claimed in claim 1 wherein the second deflection coil is divided into two parts, a first capacitor interconnected between said two parts and having a low impedance for signals of the repetition frequency of the first source and a high impedance for signals of the repetition frequency of the second source, and wherein the means for phase shifting comprises a transformer having a primary winding connected in series with the transductor second winding, means connecting said series combination in parallel with said capacitor, means connecting the secondary winding of said transformer in series with a second capacitor across the two parts of the second deflection coil, said capacitor having a low impedance for signals of the repetition frequency of the first source and a high impedance for signals of the repetition frequency of the second source, a blocking circuit tuned to the frequency of the first current source, and means for coupling said blocking circuit between the second current source and the assembly comprising said second deflection coil, said transformer, said second transductor winding, and said first and second capacitors.

9. A circuit as claimed in claim 1 wherein the transductor core is a single core comprising a central limb and two external limbs with upper and lower yokes arranged to form two closed interconnected magnetic circuits, said first transductor winding being divided into two parts connected in series and oppositely wound on the two external limbs, whereas the second winding is wound on the central limb, wherein the external limbs of the core are bevelled in a ratio of 2:1.

10. A television deflection system comprising horizontal and vertical deflection coils, a first source of current of line deflection frequency coupled to said horizontal deflection coil, a second source of current of frame deflection frequency coupled to said vertical deflection coil, and raster distortion correction means comprising, a transductor having first and second windings wound on a saturable core, said first winding comprising a pair of oppositely wound winding segments connected in series, means connecting said first winding in parallel with said horizontal deflection coil, means connecting said second transductor winding to said second current source so that a

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current of the frame deflection frequency flows therein thereby to vary the inductance of said first transducer winding at the frame deflection frequency, phase shifting means coupled to said second transducer winding and arranged to produce a phase shift of approximately 180° in a voltage of said line deflection frequency induced in said second winding, and means for coupling the phase shifted voltage of line frequency to said vertical deflection coil, the resistance and inductance of said vertical coil being proportioned so as to integrate the voltage of line frequency applied thereto.

11. A system as claimed in claim 10 wherein said second transducer winding is connected in series with said vertical deflection coil across said second current source, and wherein said phase shifting means comprises a capacitor connected in parallel with said second transducer winding so as to form therewith a resonant circuit tuned to a frequency below the line deflection frequency.

12. A system as claimed in claim 10 wherein said phase shifting means comprises a transformer having a primary and a secondary winding, a capacitor having a low impedance to line frequency signals and a high impedance for frame frequency signals, means connecting said transformer primary winding and said capacitor in series across said second transducer winding, and means connecting said transformer secondary winding in series with the vertical deflection coil across said second current source.

13. A system as claimed in claim 12 further comprising a second capacitor connected in shunt with said second current source and having a low impedance to line frequency signals and a high impedance to frame frequency signals.

14. A system as claimed in claim 10 wherein said vertical deflection coil comprises first and second equal coil segments, a first capacitor having a low impedance to line frequency signals and a high impedance to frame frequency signals, means connecting said first coil segment, said first capacitor, and said second coil segment in series across said second current source, and wherein said phase shifting means comprises a transformer having a primary and a secondary winding, a second capacitor having a low impedance to line frequency signals and a high impedance to frame frequency signals, means connecting

said transformer primary winding in series with the second transducer winding across said first capacitor, and means serially connecting said second capacitor and said transformer secondary winding across the series combination of said first and second coil segments and said first capacitor.

15. A system as claimed in claim 14 further comprising an LC parallel resonant circuit connected in series between said second current source and the parallel circuit including said first and second capacitors, said first and second coil segments, and said transformer secondary winding.

16. A television deflection system comprising horizontal and vertical deflection coils, means for applying a periodic signal of line deflection frequency to said horizontal deflection coil, means for applying a periodic signal of frame deflection frequency to said vertical deflection coil, and raster distortion correction means comprising, a transducer having first and second windings wound on a saturable core, said first winding comprising a pair of oppositely wound winding segments connected in series, means connecting said first winding in parallel with said horizontal deflection coil, means connecting said second transducer winding in series with said vertical deflection coil, a capacitor, an inductor, and means connecting said capacitor and inductor in series across said second transducer winding, said inductor, capacitor and second transducer winding forming a resonant circuit tuned to a frequency substantially below the line deflection frequency, and said vertical deflection coil has an inductance value to produce integration of line frequency signals.

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