

Dec. 20, 1949

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FOR TELEVISION DEFLECTING SYSTEM

2,492,090

Filed Nov. 3, 1948

2 Sheets-Sheet 1

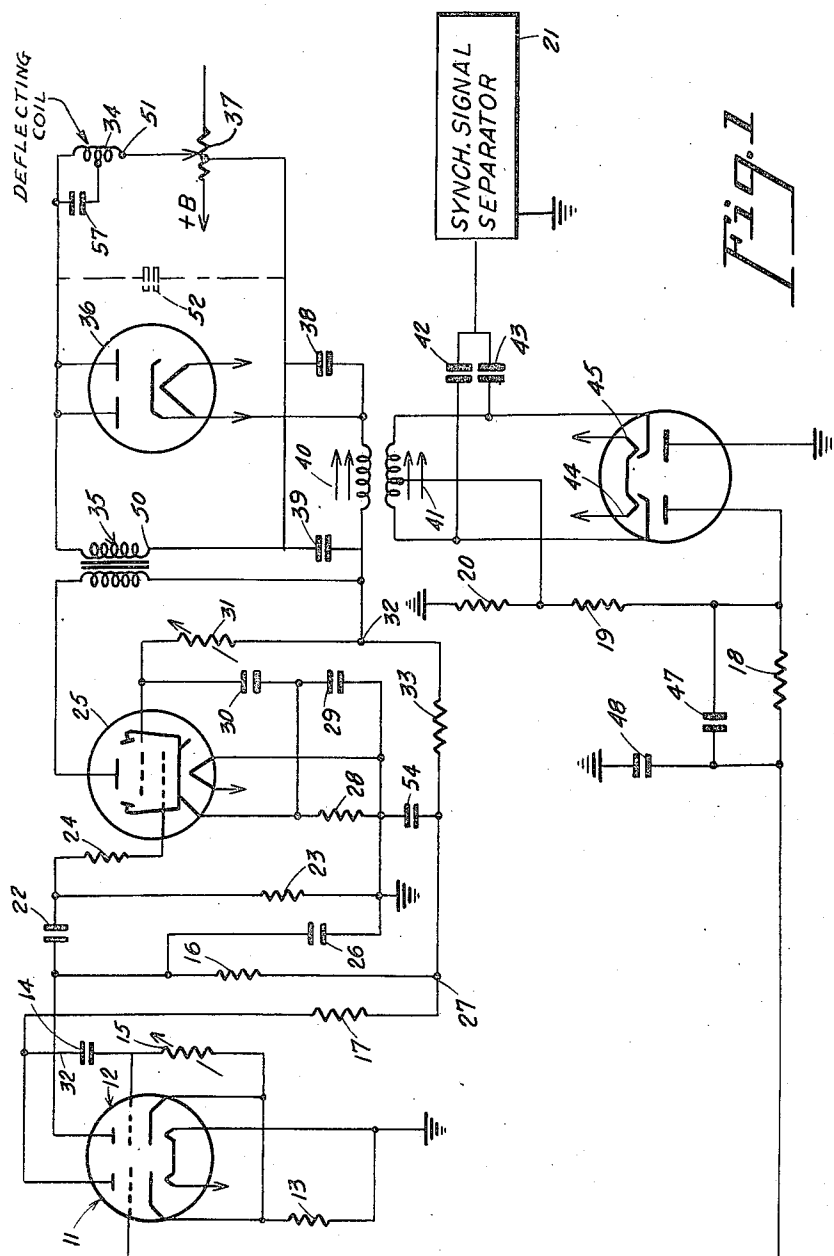


Fig. 1

INVENTOR.
HARLAND A. BASS.
BY
Alden P. Redfield.
ATTY.

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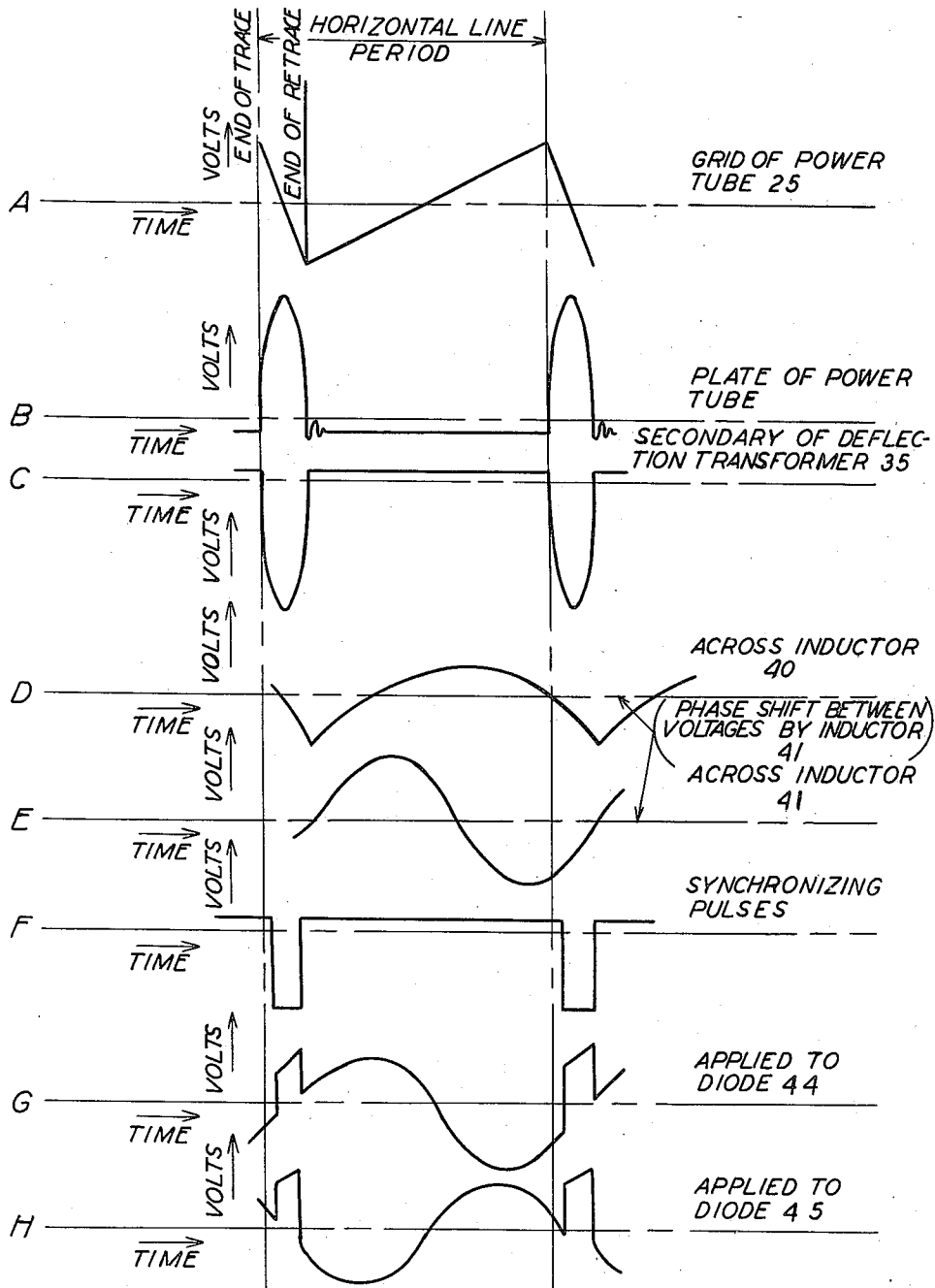


Fig. 2.

INVENTOR.
HARLAND A. BASS.
BY
Alden Q. Redfield.
ATTY.

UNITED STATES PATENT OFFICE

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AUTOMATIC FREQUENCY CONTROL CIRCUIT FOR TELEVISION DEFLECTING SYSTEMS

Harland A. Bass, Mount Healthy, Ohio, assignor to Avco Manufacturing Corporation, Cincinnati, Ohio, a corporation of Delaware

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5 Claims. (Cl. 315-27)

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The present invention relates to improvements in automatic frequency control systems of the type employed in the deflection systems of television receiver circuits. While not limited to utility in a horizontal deflection system, the invention is of particular advantage therein.

Reference is made to the automatic frequency control system shown in Fig. 11.1 following page 278 and described at pages 294 et seq. of the book "Television Simplified," by Kiver, second edition, D. Van Nostrand, Inc., New York, 1948, wherein horizontal synchronizing (sync) pulses and horizontal oscillator output signals are applied to a comparator or horizontal sync discriminator and utilized to derive a corrective control potential. This control potential has a magnitude and polarity proportional to the deviation between the oscillator output signal phase and the sync pulse phase. The unidirectional control potential is employed to control a reactance tube, which causes apparent changes in the oscillator tank circuit in such a way as to eliminate the deviation. The oscillator is a sine-wave oscillator which controls a sawtooth wave generator.

In prior art circuits in which a sawtooth oscillator is employed for initiating the sweep currents, the automatic frequency control potential is derived by measuring the phase relationships between synchronizing signals and sawtooth signals. This relationship is very critical, because of the short duration of the trailing portion of the sawtooth. It is well known that a more effective method for obtaining the automatic frequency control potential is to measure the phase relationships between sine-wave signals and synchronizing pulse signals. However, in systems which do not provide a separate sine-wave oscillator, no means has heretofore been developed for producing the sine-wave.

A primary object of the invention is to provide an automatic frequency control circuit in which the above-mentioned separate sine-wave oscillator tube is eliminated.

In the above-mentioned prior art system, the horizontal oscillator (sine-wave) circuit is coupled to a horizontal discharge tube, which in turn is coupled to a horizontal output tube or power amplifier. The amplifier output is applied to the horizontal deflecting coil or yoke of the picture tube. There is provided, in the network between the horizontal output tube and the deflecting coils, a damper tube and a linearity control circuit comprising a delay network including an inductance. A further basic object of the

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present invention is to provide a circuit for utilizing this inductance as a high-level power source of data signals, representative of the response of the deflecting coil, which data signals are compared with the sync pulses to develop a frequency control potential. This control potential is functionally related to the phase deviation between sync signals and deflecting coil current waves and is employed so to control an oscillator as to eliminate the deviation.

For a better understanding of the present invention, together with other and further advantages, capabilities and objects thereof, reference is made to the accompanying drawings and to the appended claims. In the drawings, Fig. 1 is a circuit schematic of an illustrative preferred form of automatic frequency control system in accordance with the invention, and Fig. 2 is a set of curves employed in describing the operation of the invention.

The automatic frequency control system herein shown comprises a generator for generating a deflection signal having a frequency at least in part determined by the unidirectional control potential applied thereto. This generator or cathode-coupled multivibrator is per se well known to the art and is of the general type described in prior art literature, including "Principles of Radar," M. I. T. Staff, second edition, 1946, pages 2-53 to 2-58, McGraw-Hill, New York city, and an article by J. L. Potter, pages 213 et seq., "Proceedings of the Institute of Radio Engineers," June 1938, vol. 26, No. 6, published by the Institute of Radio Engineers at New York, New York. It consists of a pair of triode tubes or equivalent 11, 12 having a common cathode resistor 13 for coupling the output of triode 12 to triode 11, a resistance-capacitance network 14, 15 for coupling the anode circuit of triode 11 to the grid circuit of triode 12, and individual anode resistors 16, 17, connected to a high potential junction point 27. The grid of triode 11 is returned to ground through a series of resistors 18, 19 and 20. Across capacitor 48 there appears a control potential which is applied to triode 11 to cause the frequency of the multivibrator output signals to correspond to that of the synchronizing signals applied to the system from a sync separator circuit 21 or other suitable source of sync pulses. It is well known to the art that the frequency of the output signals of a Potter multivibrator may be controlled by a direct current voltage applied to the grid of one of the tubes, such as tube 11.

The multivibrator is coupled, by a network

comprising anode load resistor 16, capacitor 22, grid resistor 23, and series damping resistor 24, to the input circuit of a beam-power horizontal output or power amplifier tube 25. Capacitor 26, between plate of triode 12 and ground, is the discharge capacitor across which the sawtooth sweep voltage is developed. The stage comprising high-impedance amplifier tube 25 is per se a well known prior art circuit shown in substance as the horizontal output or power tube circuit of the above-mentioned Fig. 11.1 in the Kiver book. The tube has a cathode bias resistor 28, a screen by-pass capacitor 30, a cathode by-pass capacitor 29, and a screen dropping resistor 31 connected to a high-potential point 32. A filter network comprising series resistor 33 and shunt capacitor 54 is interposed between high potential points 32 and 27.

The plate circuit of tube 25 is coupled to the horizontal deflecting coil 34 of a picture tube (not shown) through the primary of an output or deflection transformer 35. Plate voltage for the system is supplied from a centering-control potentiometer 37, comprising a resistance having leads connected between +B and ground, the sliding contact of this potentiometer being connected to one lead of coil 34 and a fixed tap on the resistance being connected to one lead 50 of the secondary of transformer 35, i. e. to the junction of elements 38, 39, 50.

A balancing capacitor 57 is connected across one section of deflecting coil 34 in conventional manner to balance the distributed capacitances of its two sections.

There is provided in shunt with the deflecting coil 34 a conventional damping circuit consisting of a tube 36, having a cathode and two anodes, and a series capacitor 38. This circuit damps out undesired oscillations in the circuit comprising deflecting coil 34 and its distributed and stray capacitance 52. This circuit also feeds back power to the anode circuit of tube 25 and permits the deflecting coil current to reverse with one half cycle of free oscillation during the retrace or beam-return intervals. To prevent falling off of the increase of current appearing in coil 34 during the latter part of the trace or scanion period, and to achieve greater linearity of the amplitude-time characteristic of that current, there are provided a capacitor 39, in parallel with capacitor 38, and a variable inductance 40, between capacitors 38, 39. The low potential terminal of the primary of transformer 35 is connected to the junction of inductor 40 and capacitor 39. There is developed in network 39, 40 a linearity control voltage which, as applied to capacitor 38, so varies the conduction of tube 36 as to prevent non-linearity of current flow through the deflecting coil 34 at or near the end of trace. The time when this voltage occurs is controlled by adjustment of variable delay inductance 40, which is preferably adjustably permeability tuned. This inductance is per se conventional and well known to the art, being shown in the literature, for example Tourshou Patent 2,440,418.

The plate of discharge device 25 is connected to the positive terminal (+B) of the high voltage space-current source through a D. C. path including the primary of transformer 35, inductor 40, the cathode-anode circuit of tube 36, deflecting coil 34 and potentiometer 37, so that the average voltage developed across capacitor 38 is such as to boost the power supply voltage and

permit the utilization of power recovered from the deflecting coil circuit.

The linearity control voltage across inductance 40 (curve D, Fig. 2) has a major component of line frequency, i. e., the frequency of the multivibrator. In accordance with the invention, there is provided means for deriving from this voltage and from the synchronizing-pulses a direct current control potential having an average amplitude and polarity determined by the magnitude and direction of the phase difference between the linearity control voltage waves and the synchronizing signals. This means includes a secondary inductor 41, so coupled to inductor 40 as therewith to constitute a transformer. Across the secondary 41 is a pair of series capacitors 42, 43, which tune the circuit of secondary 41 to resonance at line frequency, whereby there is developed in resonant circuit 41, 42, 43 a sine-wave voltage of line frequency.

Coupled to this resonant circuit is a horizontal synchronizing discriminator circuit, included in the means for deriving the frequency-control potential having a polarity and average amplitude determined by the direction and magnitude of the phase difference between the last-mentioned sine-wave voltage and the sync pulses. The comparator or discriminator circuit comprises a pair of diodes 44, 45, each cathode being connected to a terminal of secondary 41 whereby the sine-wave voltage is applied in push-pull to the diodes. Diode 44 has a load resistor 19 between anode and a center tap on secondary 41. Diode 45 has a load resistor 20 between its grounded anode and that center tap. Load resistors 19, 20 are connected series opposing. The sync separator sync signal output, of negative polarity, is applied between the junction of capacitors 42 and 43 and ground, therefore, in parallel or with the same polarity to the cathodes of both diodes. The sine-wave voltage derived from tuned circuit 41, 42, 43 is applied with opposite polarity to said cathodes so that there is developed by this phase discriminator circuit a D. C. voltage which has an amplitude and polarity functionally related to the amount and direction of the deviation between the phases of the sync signals and the deflecting currents. This D. C. frequency control voltage is applied to the grid circuit of multivibrator triode 11 through a network comprising resistor 18 and capacitors 47 and 48. Capacitors 48 and 47 form a voltage divider to attenuate rapid changes in the D. C. voltage from the phase discriminator such as are produced by noise or by the vertical synchronizing pulses, incompletely separated out in unit 21. This voltage divider arrangement also removes undesired disturbances caused by phase modulation in the transmitted pulses.

The discriminator per se is well known to the art and is described in the above-mentioned Kiver book, at pages 294-296.

Coming now to the operation of the system, it will be understood that successive sawtooth voltage waves at horizontal line frequency are developed across capacitor 26 and applied to the grid of tube 25. This wave has the shape illustrated in curve A, Fig. 2, linearly rising during trace as capacitor 26 charges through the charging circuit including resistor 16, point 27, resistor 33, point 32, inductance 40, tube 36, coil 34, potentiometer 37 and the space current source (not shown), and steeply falling during retrace as capacitor 26 discharges through triode 12.

The wave form of the voltage at the anode

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of the beam power tube 25 is as illustrated in curve B, Fig. 2. The pulses of high amplitude are caused by the rapid decay of current in load inductance 34 during retrace intervals when both tubes 25 and 36 are nonconductive. As shown in curve C, Fig. 2, the output transformer 35 inverts this voltage. Curve C shows the approximate shape of the voltage wave required (resistance parameters being neglected as overcome by negative resistance effects) to cause a sawtooth wave of current to flow through the deflecting coil 34. It comprises a series of relatively long steady portions of positive polarity, representing the "go" sweep or trace period, during which the output tube 25 supplies current to the deflection yoke, and alternate short square wave pulses of negative polarity, representing the intervals of retrace or "return" time, during which the output tube 25 plate current is cut off.

During trace energy is stored in the magnetic circuit of coil 34, both tubes 25 and 36 being conductive, so that there is a linear rise of current in coil 34. This means that the electron current flow through coil 34 during trace is the resultant of two electron current flows. First, there is the driving current output of tube 25, electrons flowing from the secondary terminal 50, to terminal 51, then through deflecting coil 34 back to the other secondary terminal. Second, there is the electron flow through tube 36 and coil 34, passing through coil 34 in the reverse direction from the first-mentioned current flow, representing the release of energy by coil 34, as shown in an article by Otto H. Schade, RCA Review, pages 506 et seq., vol. VIII, September 1947, No. 3, New York. The resultant current flow is a sawtooth wave approximately symmetrical with respect to a zero axis, as shown in Fig. 1 of the Schade article, page 507. When the multivibrator output goes negative, the plate current of tube 25 is suddenly cut off. The magnetic field, which has been steadily building up in the output transformer 35 and deflecting coil 34, begins to collapse. The rate of collapse is determined by the resonant frequency of the inductance and capacitance parameters in the deflecting coil system. This system is shocked into oscillation by the sudden cut-off of tube 25. Initially the voltage generated by the collapsing field is negative as applied to the plates of damping tube 36, preventing this tube from conducting. There is substantially no load across the system during one half cycle of free oscillation. At the end of this half cycle, the deflecting coil current reaches a maximum value in the direction opposite to that in which it was flowing at the end of the trace period. The induced voltage then reverses polarity, and the damping tube 36 begins to conduct. By this time the retrace has been completed, and the next trace begins.

During the retrace period, both tubes 25 and 36 are nonconductive, and the current in deflecting coil 34 is the resultant of one half cycle of free oscillation of the tuned circuit comprising coil 34 and its distributed capacitance 52. During the first quarter cycle the distributed capacitance 52 is charged and the current through coil 34 falls to zero. During the next quarter cycle the capacitance 52 discharges and causes current to flow through coil 34 in a negative sense. By the time the capacitance 52 has become discharged, the full half cycle of oscillation has become executed at the resonant frequency of the tuned circuit 34, 52, and the current through

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coil 34 is at a maximum in its negative sense. Tube 36 now becomes conductive and prevents capacitance 52 from charging in the reverse direction. Tube 36 becomes conductive at the start of the succeeding trace. The energy which was developed in the deflecting coil system by the output tube 25 during the latter part of the last trace has not been completely dissipated. Very little energy was lost during the first half cycle of retrace because the damping tube was nonconductive and the circuit is designed for low loss. When, after the half cycle of oscillation, the damping tube does begin to conduct, it places such a heavy load across the deflection coil system that further oscillation is prevented. During the initiation of the above-mentioned succeeding trace, the energy field decays at a rate determined by the load of the damping tube across the coil. This damping tube causes the oscillatory voltage to decay in essentially a linear manner. The output tube 25 begins to conduct again at the beginning of this successive trace, and the additional power supplied by the output tube in conjunction with the decay current in the deflection system produces a linear trace motion of the electron beam on the picture tube (not shown). These principles are explained fully in Blumlein Reissue Patent Re. 20,400.

It will be noted that tube 36 and capacitor 38 are effectively connected as a series combination in parallel with deflecting coil 34. The steady biasing potential developed across capacitor 38 for tube 36 is utilized as a part of the anode potential for the power output tube 25. This power feed-back expedient is shown in the literature, such as in Bahring Patents 2,320,555 and 2,308,908 and other publications.

As tube 36 becomes conductive, oscillations in tuned circuit 34, 52 are damped, and energy in storage in the magnetic field of deflecting coil 34 at the end of retrace is discharged in a controlled manner.

The current through damper tube 36 is made to decrease at a more rapid rate, during scanion or trace, for purposes of linearity control, by developing across capacitor 39 a voltage which is applied to capacitor 38 through the delay inductor 40. The positive peak of this voltage normally occurs substantially at the mid-point of the scanning portion of the deflection cycle. This voltage across capacitor 39 is derived from the plate current of tube 25 and is illustrated as to wave form in curve D (Fig. 2). This voltage is applied to capacitor 38, being delayed as to phase by inductor 40. The amount of the delay can be adjusted by variation of the inductance parameter of unit 40. Although it is not necessary that the theory of operation of an invention be known, or that the theory of operation of prior art elements included therein be explained, applicant believes that the foregoing explanation of the development of the linearity control voltage is correct. Some authorities believe that the voltage across capacitor 38 varies, due to the charging by the deflection coil kick-back and the discharging through the output tube 25. The rise and fall of this voltage is equivalent to an alternating current ripple in the anode supply for the output tube 25. Those authorities believe that inductor 40 and capacitor 39 form a phase-shift network and delay network, which so shifts the phase of this ripple as to alter the characteristic of the output tube 25. Inductor 40 is variable to provide the desired improvement in linearity. However the opera-

tion of the delay network be regarded, it is well known to the art that a linearity control voltage having a large component of line frequency appears across inductor 40.

It will be seen that the linearity control voltage appearing across inductor 40 has a major component of the same frequency as the current pulses in deflecting coil 34. In accordance with the invention this voltage is used to produce data signals which are compared with the synchronizing pulses to derive the automatic frequency control voltage. The voltage across inductor 40 is converted into a sine wave by coupling inductor 40 to a tuned secondary circuit 41, 42, 43. A separate sine-wave generating tube is thus eliminated.

The sine-wave signals are applied with opposite polarity to the two diodes 44, 45, tending to make them alternately conductive. The synchronizing pulses are applied with the same polarity to both diodes, tending to render them simultaneously conductive. For purposes of discussion it will be assumed that each sync pulse normally occurs as the sine wave is going through zero.

If the synchronizing pulses arrive (curve F, Fig. 2) when the sine-wave voltage across tuned circuit 42—43 is zero, then each diode 44, 45 (curve G, H, Fig. 2) will receive the same pulse voltage and the same amounts of rectified voltage will appear across load resistors 19 and 20. The total net output from both tubes will be zero, because the load resistors are coupled in opposition.

If the sync pulses arrive when diode 45 is cut off and diode 44 is conducting, the average voltage developed across resistor 19 will be greater than that across resistor 20. This average voltage, over one cycle, will be negative as applied to the grid of tube 11. On the other hand, if the sync pulses arrive when diode 45 is conducting and diode 44 is cut off, the average voltage across resistor 20 will prevail and will be positive as applied to the multivibrator input. It is understood, therefore, that the double-diode horizontal synchronizing discriminator is a sensitive phase discriminator which develops an output voltage that may be negative, zero or positive (to slow down, maintain at steady speed, or speed up the multivibrator), depending on the phase of the synchronizing pulses with respect to the sine-wave voltage generated in the tuned circuit 41, 42, 43 coupled to the delay inductor 40. In this manner, any undesired deviation between sync pulses and deflection rate is rapidly eliminated.

The multivibrator normally operates at 15,750 cycles per second in a horizontal deflecting system under present standards, and the sync pulses have that frequency. The circuit 41, 42, 43 is tuned to the large 15,750 cycle component of the voltage appearing across the linearity control inductor 40.

The following parameters were found suitable in one successful commercial embodiment of the invention:

Triodes 11, 12	Type 7N7 tube
Tube 25	Type 6BG6
Tube 36	Type 5V46
Resistor 13	1000 ohms
Resistor 15	500,000 ohms
Capacitor 14	82 mmf.
Resistor 17	47,000 ohms
Resistor 16	1 megohm
Capacitor 22	0.01 mf.
Capacitor 26	150 mmf.
Resistor 23	1 megohm

Resistor 24	47 ohms
Resistor 28	100 ohms
Resistor 33	10,000 ohms
Capacitor 54	0.05 mf.
Capacitor 29	0.1 mf.
Capacitor 30	0.05 mf.
Resistor 31	50,000 ohms
Capacitor 39	0.06 mf.
Capacitor 38	0.05 mf.
Capacitor 57	56 mf.
Resistor 20	100,000 ohms
Resistor 19	100,000 ohms
Resistor 18	470,000 ohms
Capacitor 47	0.004 mf.
Capacitor 48	0.05 mf.
Capacitor 42	0.005 mf.
Capacitor 43	0.005 mf.

While there has been shown and described what is at present considered the preferred embodiment of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention as defined by the appended claims.

Having fully disclosed and described my invention, I claim:

1. In an automatic frequency control system for a television picture tube deflecting system, said system being of the type which comprises a deflecting coil, a multivibrator circuit for originating the voltage wave for said deflecting system, an amplifier circuit employing a high impedance electron tube for generating the deflecting current for said coil and a damper tube circuit shunted across said coil and including a delay inductor, said system being controlled as to frequency by a pulse form synchronizing wave, the improvement which comprises a tuned circuit inductively coupled to said delay inductor for deriving a sine wave of voltage synchronized with said deflecting current and a comparator circuit for deriving from said sine-wave voltage and said pulse form synchronizing voltage a voltage for controlling the phase and frequency of said multivibrator.

2. In an automatic frequency control system for a television picture tube deflecting system, said system being of the type which comprises a deflecting coil and signal generator for generating a deflection signal having a frequency at least in part determined by a control potential applied thereto, which control potential is indirectly derived from synchronizing signals, electron beam-deflecting means for coupling said generator to said coil whereby to produce periodic beam-deflecting waves therein, a discharge device for damping out undesired oscillations across said coil, and means for developing a linearity control voltage which varies as a function of the current in said coil, the improvement which resides in the combination of means for deriving from said linearity control voltage and from said synchronizing signals a frequency control potential having a direction and magnitude determined by the direction and magnitude of the phase difference between said voltage and said synchronizing signals and means for applying said frequency control potential to said signal generator to eliminate said phase difference.

3. In an automatic frequency control system for a television picture tube deflecting system, said system being of the type which comprises a deflecting coil and signal generator for generating a deflection signal having a frequency at

least in part determined by a control potential applied thereto, which control potential is indirectly derived from synchronizing signals, electron beam-deflecting means for coupling said generator to said coil whereby to produce periodic beam-deflecting waves therein, a discharge device for damping out undesired oscillations across said coil, and means for developing a linearity control voltage which varies as a function of the current in said coil, the improvement which resides in the combination of means including a phase discriminator for deriving from said linearity control voltage and from said synchronizing signals a frequency control potential having a direction and magnitude determined by the direction and magnitude of the phase difference between said voltage and said synchronizing signals, and means for applying said frequency control potential to said signal generator to eliminate said phase difference.

4. In an automatic frequency control system for a television picture tube deflecting system, said system being of the type which comprises a deflecting coil and signal generator for generating a deflection signal having a frequency at least in part determined by a control potential applied thereto, which control potential is indirectly derived from synchronizing signals, electron beam-deflecting means for coupling said generator to said coil whereby to produce periodic beam-deflecting waves therein, a discharge device for damping out undesired oscillations across said coil, and means including a delay inductor for developing a linearity control voltage which varies as a function of the current in said coil, the improvement which resides in the combination of means for deriving from said linearity control voltage and from said synchronizing signals a frequency control potential having a direction and magnitude determined by the direction and magnitude of the phase difference between said voltage and said synchronizing signals, and means for applying said control po-

tential to said signal generator to eliminate said phase difference, said means comprising a tuned circuit coupled to said delay inductor, a phase discriminator having two diodes coupled in push-pull to said tuned circuit whereby the sine-wave voltage developed across said tuned circuit is applied to the diodes in push-pull, and a coupling network for applying said synchronizing signals in parallel to said diodes.

5. In an automatic frequency control system for a television picture tube deflecting system, said system being of the type which comprises a deflecting element and a signal generator for generating a deflection signal having a frequency at least in part determined by a control potential applied thereto, which control potential is indirectly derived from synchronizing signals, electron beam-deflecting means for coupling said generator to said element whereby to produce periodic beam-deflecting waves therein, and linearity control means, the improvement which resides in the combination of means coupled to the linearity control means and responsive to the voltage developed thereacross and to said synchronizing signals to derive a control potential having a direction and magnitude determined by the direction and magnitude of the phase difference between said voltage and said synchronizing signals, and means for applying said control potential to said signal generator to eliminate said phase difference.

HARLAND A. BASS.

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