United States Patent

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[54] **POWER SUPPLY CIRCUIT FOR USE WITH X-RAY GENERATING DEVICE FOR CINE-RADIOGRAPHY**
8 Claims, 22 Drawing Figs.

[52] **U.S. Cl.** **250/65;** 250/102
[51] **Int. Cl.** **H05g 1/14,** H05g 1/60
[50] **Field of Search** 250/65, 102

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ABSTRACT: Cineradiography wherein an AC sinusoidal input is converted by an inverter using controlled rectifiers into rectangular pulses in synchronism with shutter opening signals provided by a cinecamera, and the rectangular pulses in turn are boosted to high voltage pulses which are applied to the anode of an X-ray tube so as to produce pulselike X-rays of optional time-width required for photographing only during the period when the shutter is opened, thereby minimizing the dosage to which a patient is exposed. Thus, the device described herein is advantageous over the conventional devices in which pulse like X-rays are generated under the control of the grid of an X-ray tube, in that the former can be constructed at lower cost, and that high-speed cinephotographying can be carried out since the number of frames per second can be selected irrespective of the frequency of the power source.

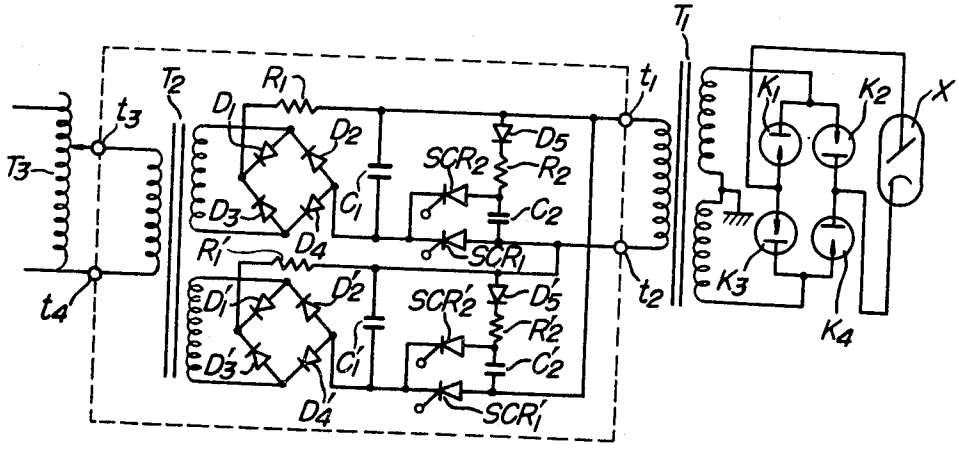


FIG. 1

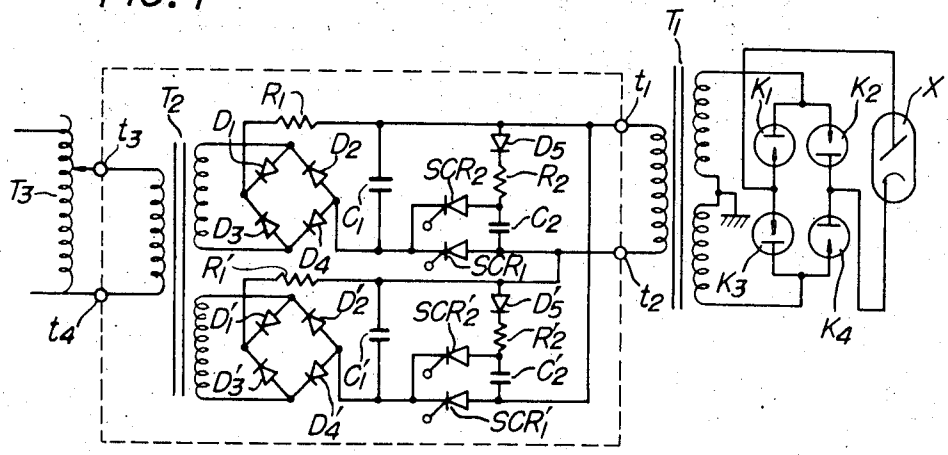


FIG. 2

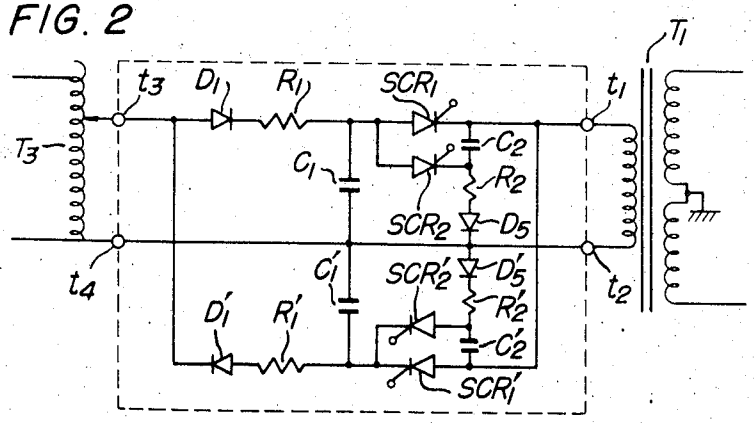
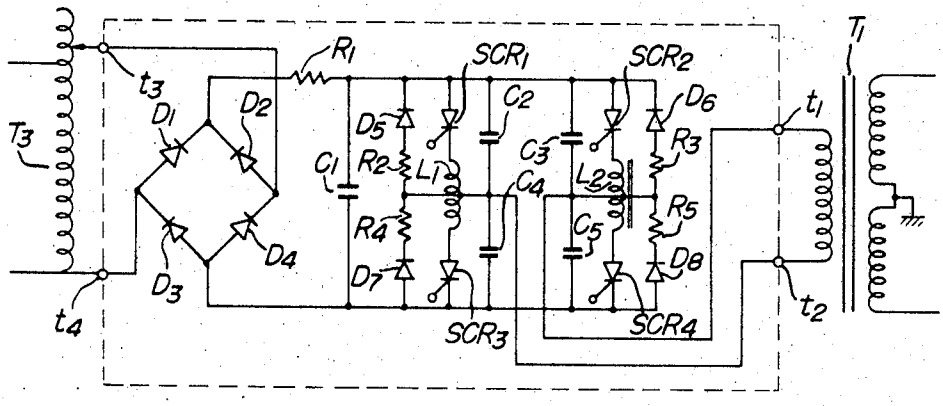


FIG. 3



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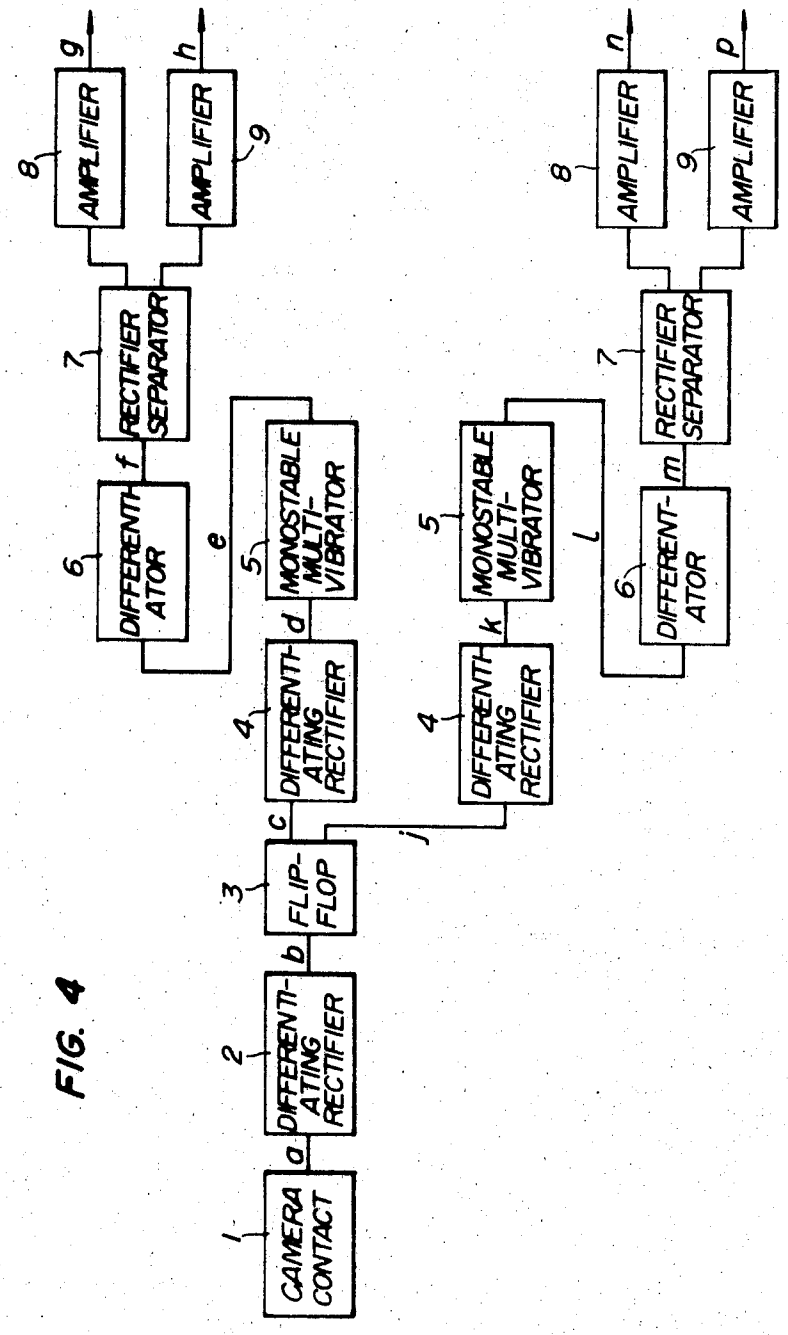


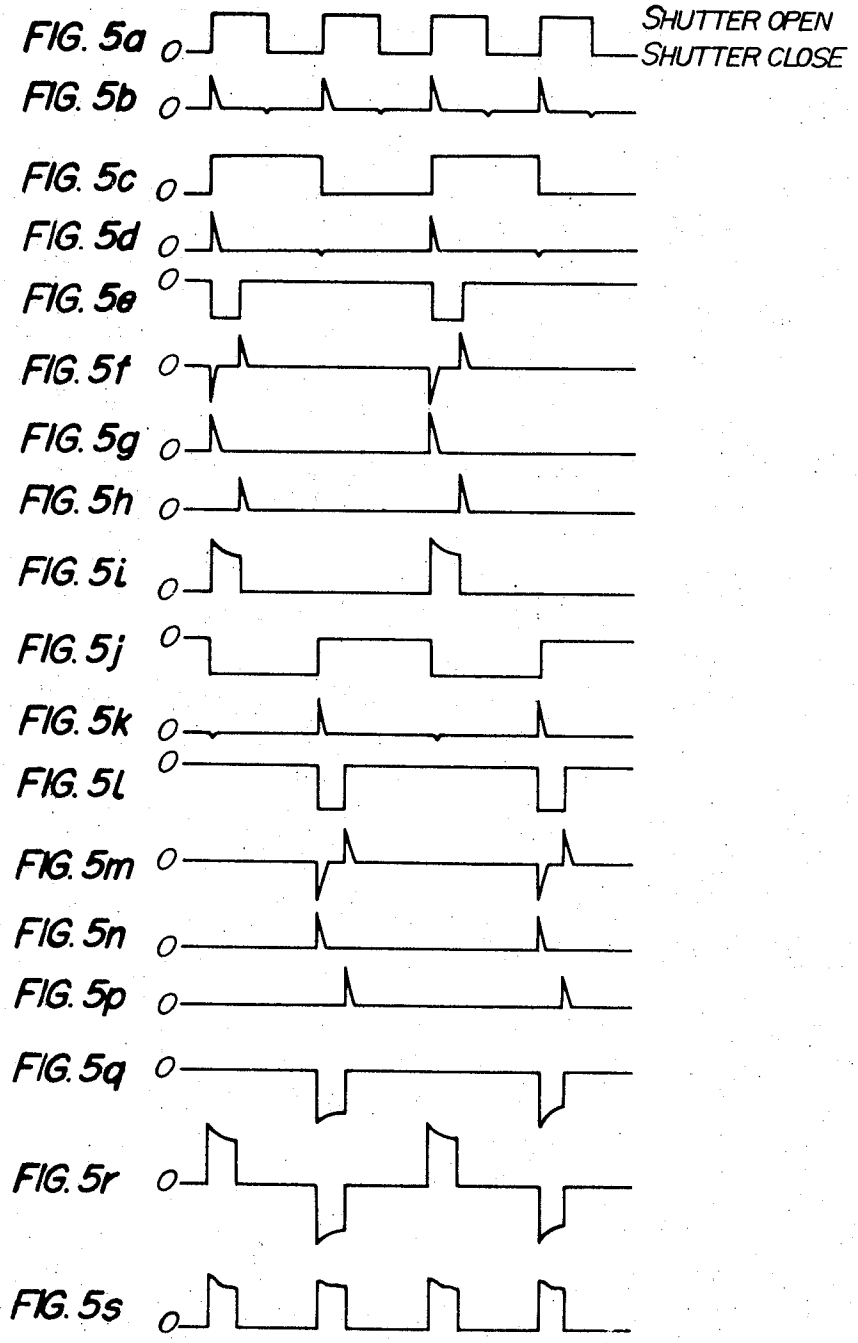
FIG. 4

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POWER SUPPLY CIRCUIT FOR USE WITH X-RAY GENERATING DEVICE FOR CINE-RADIOGRAPHY

This invention relates to an X-ray generating device for cine-radiography and more particularly pertains to improvements in the power supply circuit for use with such device for generating pulse-like X-rays of short duration only during the time when the shutter of a cine-camera is opened.

In an attempt to achieve cine-radiography of moving internal organs such as the heart, it has long been desired to be able to decrease the dosage to which a patient is exposed. Recently, there has been developed a device using a three-electrode X-ray tube and so designed that by intermittently effecting X-ray irradiation in synchronism with the opening of the shutter of a cine-camera, the time of irradiation can be decreased so as to be of the order of milliseconds irrespective of the number of frames to be photographed per second. Consequently, it is possible to prevent X-rays from being wastefully irradiated during the time when the shutter is closed so that the dosage can be reduced by half or more, and it is also possible to reduce the possibility that the photograph becomes blurred due to movement of the object to be photographed.

In order to operate a three-electrode X-ray tube in an ordinary full-wave rectification type high voltage generating device, however, it is required that the grid control signal for effecting intermittent X-ray irradiation be in synchronism with the phase of the power source. This restricts the number of frames to be photographed per seconds, and in addition it is very difficult to achieve such synchronism without using a special camera adapted to be driven by means of a synchronous motor. By adopting a method of applying to the X-ray tube a rectified voltage smoothed out by a high voltage condenser additionally provided in the full-wave rectifier circuit, it is possible to generate pulselike X-rays of an optional cyclic period irrespective of the phase of the power source and avoid the restriction described above. However, the high voltage condenser is required in addition to the three-electrode X-ray tube, which increases the cost of the device correspondingly.

An object of this invention is to provide a practical device for generating pulselike X-rays in synchronism with external signals such as the shutter opening signals provided by a cine-camera, said device comprising rectifier-smoother circuit means for converting an AC sinusoidal input from a commercial AC power source into a DC voltage, DC chopper circuit means composed of controlled rectifiers and connected with the output of said rectifier-smoother circuit means, means for supplying a control signal to said DC chopper circuit means in accordance with shutter opening signals provided by the cine-camera so as to produce rectangular pulses in synchronism with said shutter opening signals at the output side of said DC chopper circuit means, and means for boosting the output pulses of said DC chopper circuit means to high voltage pulses and applying the latter to the anode of an X-ray tube, wherein pulselike X-rays of optional time-width can be produced with the application of said high voltage pulses every time when the shutter of the cine-camera is opened.

FIGS. 1 to 3 are circuit diagrams showing embodiments of this invention.

FIG. 4 is a block diagram showing the control signal circuit for operating the devices shown in FIGS. 1 to 3.

FIGS. 5*a* to 5*s* are graphs showing voltage waveforms.

In the arrangement shown in FIG. 1, the portion enclosed by a dotted line is an inverter for converting an AC sinusoidal input into rectangular pulses which comprises a pair of DC chopper circuits one of which is constructed by connecting controlled rectifiers SCR_1 and SCR_2, a bypass capacitor C_2, a rectifier D_5 and a resistor R_2 to the output of a rectifier-smoother circuit consisting of bridge-connected rectifiers D_1 to D_4, a smoothing capacitor C_1 and a resistor R_1 as shown in the drawing, and the other chopper circuit being constructed similarly by connecting controlled rectifiers SCR_1' and SCR_2' a bypass capacitor C_2'a rectifier D_5' and a resistor R_2' to the output of a rectifier-smoother circuit consisting of rectifiers D_1' to D_4'a capacitor C_1' and a resistor R_1'. The output terminals of said pair of DC chopper circuits are connected with primary terminals t_1 and t_2 of a high voltage transformer T_1 in opposite polarity relationship with each other, and the inputs of the rectifiers D_1 to D_4 and D_1' to D_4' are connected with output terminals t_3 and t_4 of a tube voltage regulator T_3 through an isolating transformer T_2. That is, said pair of DC chopper circuits form inverse-parallel circuits each including a separate DC power source. The secondary winding of the high voltage transformer T_1 is connected across the electrodes of a diode X-ray tube X through an ordinary full-wave rectifier circuit composed of rectifier tubes K_1 to K_4.

Referring to FIG. 4, there is shown an example of a control signal circuit for operating the inverter. In FIG. 4, the reference numeral 1 represents a contact adapted for interlocking with the opening and closure of a shutter provided in the cine-camera, 2 and 4 differentiating rectifier circuits, 3 a flip-flop circuit, 5 a monostable multivibrator circuit, 6 a differentiating circuit, 7 a rectifier-separating circuit, and 8 and 9 amplifier circuits. A shutter opening signal *a* produced by the camera contact 1 is differentiated and rectified, and a resulting positive pulse *b* is supplied to the flip-flop circuit which in turn provides two outputs having a frequency two times as high as that of the shutter-opening signal *a* and 180° out of phase with the latter. One of the outputs *c* is differentiated and rectified, and a resultant positive pulse *d* is supplied to the monostable multivibrator circuit. A rectangular wave output *e* produced by the monostable multivibrator circuit is differentiated and then resulting positive and negative pulses *f* are rectified, separated and amplified into trigger signals *g* and *h* which in turn are supplied to the gates of the controlled rectifiers SCR_1 and SCR_2 of FIG. 1, respectively. The other of the output *j* is converted into trigger signals *n*, *p* through the same process of *k*—*l*—*m* and applied to the gates of the controlled rectifiers SCR_1' and SCR_2' of FIG. 1. As shown in FIG. 5, trigger signals *g*, *h* and *n*, *p* are alternately produced during the period when the shutter opening signal *a* appears.

Description will now be made of the operation of the inverter which is effected by the trigger signals. If the trigger signal *g* is applied to the gate of the controlled rectifier SCR_1, then the latter is rendered conductive so that a positive DC voltage smoothed out by the condenser C_1 appears across the terminals t_1 and t_2. At the same time, the bypass capacitor C_2 is charged so that the trigger signal *h* is subsequently caused to arrive at the gate of the controlled rectifier SCR_2. When the rectifier SCR_2 is rendered conductive, the rectifier SCR_1 is cut off by the voltage of the condenser C_1. No voltage will appear on the output side until the rectifier SCR_1 is again rendered conductive.

The rectifier SCR_2 is subsequently rendered conductive, but it is short-circuited through the condenser C_2 at the moment that the rectifier SCR_2 is rendered conductive by the trigger signal *g*, so that the rectifier SCR_2 is cut off. Thus, the rectifiers SCR_1 and SCR_2 are alternately made conductive by the trigger signals *g* and *h*, with a result that a positive rectangular pulse is available across the terminals t_1 and t_2, as shown in FIG. 5*i*.

In the same way, the rectifiers SCR_1' and SCR_2' are also alternately rendered conductive by the trigger signals *n* and *p*, with a result that a negative rectangular pulse becomes available across the terminals t_1 and t_2 as shown in FIG. 5*q*.

The outputs of the DC chopper circuit formed by the rectifiers SCR_1 and SCR_2 and that constituted by the rectifiers SCR_1' and SCR_2' are added each other and applied to the primary side of the high voltage transformer in the form of axially symmetrical rectangular pulses which are alternately reversed in polarity as shown in FIG. 5*r*. Thus, the voltage applied to the X-ray tube assumes such a waveform as shown in FIG. 5*s*, so that pulselike X-rays are produced in synchronism with the opening of the shutter of the cine-camera.

The cyclic period of the pulses thus produced depends only upon that of the synchronizing signal (shutter opening signal) irrespective of the phase of the power source, and their width can be optionally selected by changing the time constant of

the monostable multivibrator provided in the signal circuit. In the example shown in FIG. 2, a half-wave rectifier circuit comprised of rectifiers D_1 and D_1' is provided in the DC power source for the inverter, and the isolating transformer (as indicated by T_2 in FIG. 1) is omitted. Except for this, the embodiment of FIG. 2 is similar to that of FIG. 1 in respect of construction and operation.

In FIG. 3, there is shown an example in which an inverter is constructed by the use of a rectifier-smoother circuit and bridge-connected DC chopper circuits.

Controlled rectifiers SCR_1, SCR_3 and SCR_4 are connected as the respective arms of the bridge in such a manner that the controlled rectifiers SCR_1 and SCR_4 form one of the DC chopper circuits and the controlled rectifiers SCR_2 and SCR_3 constitute the other DC chopper circuit. The respective DC chopper circuits have their inputs connected with the output of the rectifier-smoother circuit formed by rectifiers D_1 to D_4, smoothing capacitor C_1 and resistor R_1 and their outputs connected with the primary terminals t_1 and t_2 of the high voltage transformer T_1 in opposite polarity relationship to each other.

The input of the rectifiers D_1 to D_4 is connected across output terminals t_3 and t_4 of tube voltage regulator T_3, and the secondary winding of the high voltage transformer T_2 is connected with the electrodes of the two-electrodes X-ray tube through the full-wave rectifier circuit, as shown in FIG. 1. Symbols C_2 to C_5 represent bypass capacitors, L_1 and L_2 bypass reactors, D_5 to D_8 feedback rectifiers, and R_2 to R_5 feedback resistors.

The control signal circuit as shown in FIG. 3 can be utilized as it is. Thus, the signal *g* is supplied to the gate of the controlled rectifiers SCR_1 and SCR_4, the signal *h* to the gate of the controlled rectifier SCR_3, the signal *n* to the controlled rectifiers SCR_2 and SCR_3, and the signal *p* to the gate of the controlled rectifier SCR_4.

With the arrangement of FIG. 3, upon arrival of the signal *g*, the controlled rectifiers SCR_1 and SCR_4 are rendered conductive so that a positive voltage such as shown in FIG. 5*i* appears across the t_1 and t_2. . When the controlled rectifier SCR_3 is rendered conductive by the subsequent signal *h*, the capacitor C_4 is caused to discharge so that a voltage is induced across the reactor L_1, whereby the controlled rectifiers SCR_1 and SCR_4 are cut off. Subsequently, the controlled rectifier SCR_3 is also cut off. Upon arrival of the signal *n*, the controlled rectifiers SCR_2 and SCR_3 are rendered conductive so that a negative voltage such as shown in FIG. 5*q* appears across the terminals t_1 and t_2, and when the controlled rectifier SCR_4 is rendered conductive by the next signal *p*, the capacitor C_5 is caused to discharge so that a voltage is induced across the reactor L_2 whereby the controlled rectifiers SCR_2 and SCR_3 are cut off. Subsequently, the controlled rectifier SCR_4 is also cut off. As a result of repetition of the operation as described above, axially symmetrical rectangular pulses as shown at *r* which are the combination of FIG. 5*i* and 5*q* are applied to the primary winding of the high voltage transformer, so that the voltage applied to the X-ray tube assumes a pulse waveform in synchronism with the shutter opening signals as shown in FIG. 5*s*.

The advantages of this invention are as follows:

1. Since pulselike X-rays persisting for a short period of time are produced only during the time when the shutter of the camera is opened, the dosage to which a patient is exposed in the production of cine-radiography can be minimized, and a high-quality photograph can be obtained which is less blurred due to motion of an object to be photographed.

2. Since there is no need to achieve synchronization with respect to the phase of the power source, no limitation is imposed upon the number of frames per second, and the power supply source embodying the present invention can be applied not only to a camera which is so designed as to be driven by means of a synchronous motor but also to any type of camera if there is only provided a signal contact.

3. Since the waveform of the tube voltage is rectangular and the pulse width can be optionally selected, high-speed photography such as that with more than 100 frames per second can also be effected which is required for cine-angiocardiography.

4. Since no three-electrode X-ray tube and high voltage condenser are needed, the total manufacturing cost of the device can be lowered, and cine-photographying can be realized merely by incorporating an inverter and control signal circuit therefor as an adapter into an ordinary full-wave rectification type X-ray device using a two-electrode X-ray tube. Thus, the circuit arrangement of this invention can be simply applied to any existing device of this type.

5. Since an input pulse applied to the high-voltage transformer is of axially symmetrical waveform, there is no possibility that the high-voltage transformer is linearly magnetized as in the cases where use is made of nonsymmetrical pulses. Consequently, the waveform is not distorted.

We claim:

1. A power supply circuit for use with an X-ray generating device for cine-radiography, comprising rectifier-smoother circuit means for converting an AC sinusoidal input from a commercial AC power source into a DC voltage, DC chopper circuit means composed of controlled rectifiers and connected with the output of said rectifier-smoother circuit means, means for supplying a control signal to said DC chopper circuit means in accordance with shutter opening signals provided by a cine-camera being independent of the voltage produced by the AC power source so as to produce rectangular pulses in synchronism with said shutter opening signals at the output side of said DC chopper circuit means, and means for boosting the output pulses of said DC chopper circuit means to high voltage pulses and applying the latter to the anode of an X-ray tube, wherein pulselike X-rays of optional time-width are generated with the application of said high voltage pulses every time the shutter is opened.

2. The power supply circuit of claim 1, wherein said means for supplying a control signal includes first means for receiving said shutter open signal from said cine-camera and for generating first and second signals each time said cine-camera delivers shutter opening signals.

3. The power supply circuit of claim 2 further including second and third means for receiving said first and second signals respectively for generating pulses alternately reversed in polarity in synchronism with the delivery of shutter opening signals by said cine-camera.

4. The power supply circuit of claim 3, wherein said second and third means each comprise a differentiating rectifier and monostable multivibrator connected in series.

5. The power supply circuit of claim 4, wherein said first means comprises a differentiating rectifier and flip-flop connected in series.

6. The power supply circuit of claim 2, wherein said first means comprises a differentiating rectifier and flip-flop connected in series.

7. A power supply circuit for use with an X-ray generating circuit for cine-radiography comprising a pair of rectifier-smoother circuits for converting an AC sinusoidal input from a commercial AC power source into a DC voltage, a pair of DC chopper circuits composed of controlled rectifiers and connected with the outputs of said rectifier-smoother circuits, means for supplying a control signal to each of said chopper circuits in accordance with shutter opening signals provided by a cine-camera independently of the voltage produced by the AC power source so as to produce rectangular pulses in synchronism with said shutter opening signals alternately at the output sides of said DC chopper circuits, means for combining the output pulses of said chopper circuits into axially symmetrical rectangular pulses which are alternately reverse in polarity, and means for boosting and rectifying said axially symmetrically rectangular pulses to high voltage pulses and applying the latter to the anode of an X-ray tube, wherein pulselike X-rays of optional time-width are generated with the application of high voltage pulses every time the shutter is opened.

8. A power supply circuit for use with an X-ray generating device for cine-radiography, comprising rectifier-smoother circuit means for converting an AC sinusoidal input from a commercial AC power source into a DC voltage, DC chopper circuit means including at least bridge-connected four controlled rectifiers connected with the output of said rectifier-smoother circuit means, means for supplying a control signal to said DC chopper circuit means in accordance with shutter opening signals provided by a cine-camera independently of the voltage produced by the AC power source so as to produce axially symmetrical rectangular pulses which are alternately reversed in polarity in synchronism with said shutter opening signals at the output side of said DC chopper circuit means, and means for boosting and rectifying the output pulses of said DC chopper circuit means to high voltage pulses and applying the latter to the anode of an X-ray tube, wherein pulselike X-rays of optional time-width are generated with the application of said high voltages every time the shutter is opened.

UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 3,564,243 Dated February 16, 1971

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It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 1, Line 11, insert -- Priority Japan
March 13, 1967, 42/15,320 --

Signed and sealed this 9th day of November 1971.

(SEAL)
Attest:

EDWARD M.FLETCHER, JR.
Attesting Officer

ROBERT GOTTSCHALK
Acting Commissioner of Pat