March 15, 1960 M. WIDAKOWICH 2,928,994

TRANSISTOR INVERTERS FOR FEEDING FLUORESCENT TUBES

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Fig.1

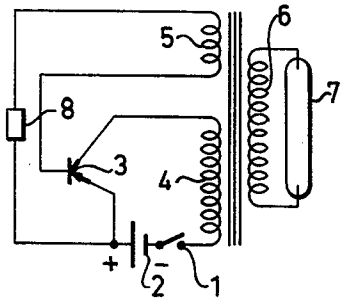

Fig.2

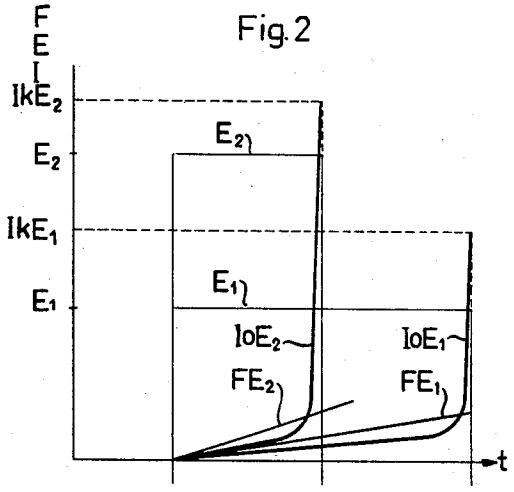

Fig.3

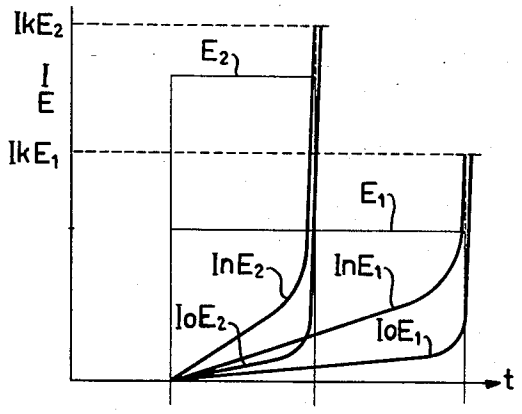

Fig.4

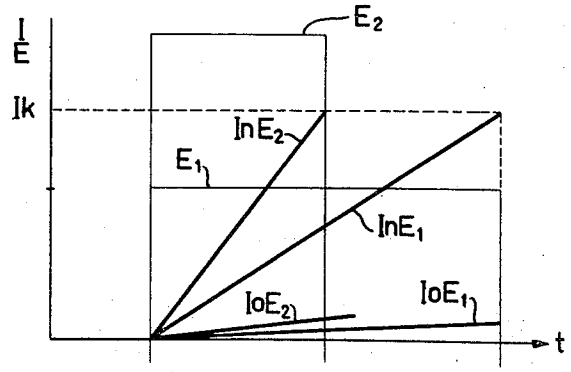

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Fig. 5

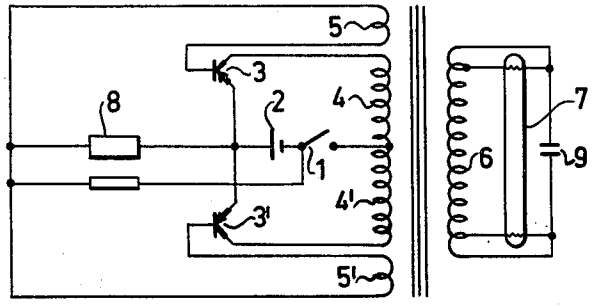


Fig. 6

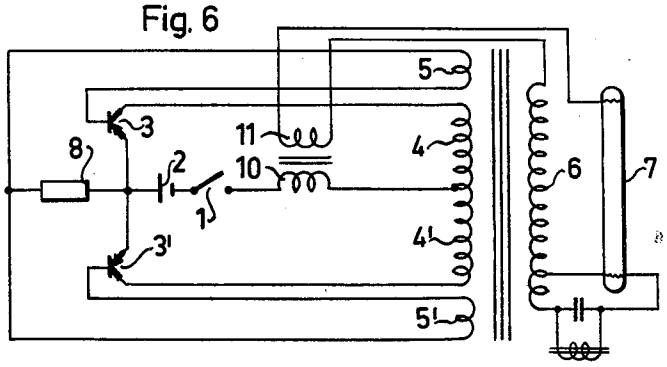
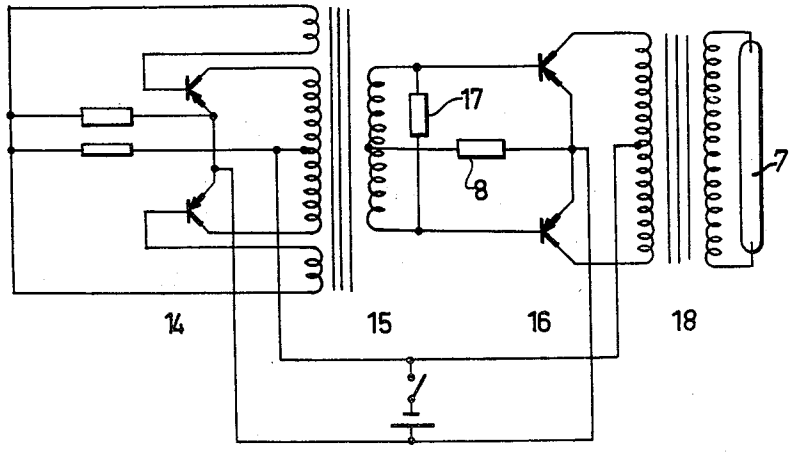


Fig. 7



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TRANSISTOR INVERTERS FOR FEEDING FLUORESCENT TUBES

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6 Claims. (Cl. 315—205)

For feeding fluorescent tubes from a direct current source (e.g. a battery) it is necessary first to invert and then to transform the voltage in order to supply the fluorescent tubes with a voltage suitable for their operation. For the inversion of the direct current devices are generally used which operate with moving contacts and/or windings. Either the inverter then feeds a transformer to which the various fluorescent tubes are connected by way of their series impedances, or each fluorescent tube or group of fluorescent tubes is fitted with a special transformer connected to the inverter, said transformer being of a current limiting design. The problem in this case is to maintain the current in the fluorescent tube constant and independent of the voltage fluctuations of the direct current source which are often great.

According to the invention a transistor inverter is used which shows such a characteristic that the current through the fluorescent tubes remains almost constant and independent of the voltage fluctuations of the direct current source. This may for instance be attained by the frequency of the inverter being changed approximately in proportion to the battery voltage, a reactive current limitation being then used. The advantage with an inverter operating according to the said principle is that it is very simple and chiefly consists only of the transistor and the transformer. If the latter is provided with a stray field and an iron core whose magnetization curve shows a pronounced knee, the fluorescent tube may be connected directly to the transformer without interposing further current limiting elements.

The invention will be described in greater detail with reference to the attached drawings showing various current circuit arrangements and diagrams in transistor inverters used for feeding fluorescent tubes.

Fig. 1 is a schematic diagram of the invention;

Figs. 2 through 4 are diagrams illustrative of various electrical values in operation of circuitry arrangements according to the invention;

Fig. 5 is a schematic diagram of an embodiment of the inverter according to the invention illustrative of transistor circuitry with the transistor connected in a push-pull configuration;

Fig. 6 is a diagram of a modification of the transistor inverter according to the invention;

Fig. 7 is a diagram of another modification of the transistor inverter according to the invention.

Figure 1 illustrates the principle of the transistor inverter. When the switch **1** is closed, the battery **2** is connected via the transistor **3** to the primary winding **4** of the transformer, the transistor then operating with joint (grounded) emitter coupling. In the core of the transformer now a flux change proportional to time arises, said flux change coming to an end, however, as soon as the exciting current reaches the limit valve determined by the collector saturation current. At this point the transistor is cut off by the voltage of the feedback winding **5** falling to zero or changing direction, respectively, after which a new pulse starts. The duration of each

pulse is thus limited by the point of time when the exciting current reaches the critical value, and the higher the battery voltage is the sooner this will take place.

Figure 2 is an idealized diagram showing the progress during the positive half-wave of magnet flux, collector current and voltage across the winding **4** in an unloaded inverter and at a battery voltage E1 as well as at the double battery voltage E2. When switch **1** is closed a small current starts to flow from the +terminal of the battery **2** via the emitter base collector of the transistor to the primary winding **4** of the transformer and back to the —terminal. Thereby a voltage is induced in the winding **5** resulting in an emitter base current which reduces the resistance of the transistor and increases the current in the winding **4**, which thus obtains practically the whole voltage E1. The voltage induced in the winding **5** is therefore constant and almost equal to the product of the battery voltage and the tranformation ratio between windings **4** and **5**. As a consequence, the current in the emitter base circuit will be constant for invariable battery voltage. It is primarily restricted by a resistor **8** which thus determines the collector saturation current Ik. In order to balance the voltage E1, the flux FE1, Figure 2, in the core of the transformer must grow proportionally to the time. This flux is generated by the no-load exciting current IoE1 which, to begin with, grows slowly, but more rapidly according as the transformer iron beomes saturated, As soon as this exciting current has reached the value of the collector saturation current IkE1, it will no longer grow. As the flux will then also stop growing the voltage of the winding **5** and therefore also the emitter base current disappears, the transistor being then choked. As a consequence thereof the collector current, that is the exciting current IoE1, vanishes. The magnet energy accumulated in the transformer iron generates a high voltage pulse in the winding **4** in the opposite direction and is dissipated, in an unloaded converter, partly in the form of iron losses and partly in the form of copper losses and losses in the transistor. If desired it may charge a capacitor connected in parallel to the transformer. When the flux has ceased falling off a new pulse starts.

Thus it is the peak value of the primary current of the transformer which determines the moment of commutation said peak value being substantially equal to the collector saturation current of the transistor. This current is primarily determined by the base emitter current flowing in that moment. If a resistor **8** of a constant value is chosen, the base emitter current becomes substantially proportional to the voltage of the battery **2**.

If the battery voltage is raised or doubled in value, to E2, the growth of the flux must proceed twice as fast, for which reason the saturation of the transformer iron will occur in half the time. The voltage induced in the winding **5** also obtains a doubled value on account of which the emitter base current is also doubled, The corresponding collector saturation current IkE2, however, will become somewhat less than the double IkE1 due to the falling current amplification characteristic of the transistor. If the core of the transformer consists of an iron material, the magnetizing curve of which shows a pronounced knee, a very short interval will elapse, however, before Io has grown from IkE1 to IkE2 in which moment the commutation at E2 takes place. As evident from Figure 2 the duration of the positive pulse will thus be practically inversely proportional to the voltage of the battery.

According to the invention the current limiting impedance necessary for the operation of fluorescent tubes is chosen as an inductance, preferably as a stray field in the transformer. The secondary current of the transformer, therefore, grows with the time, the curve for the

corresponding primary load current I_n will then run in a similar manner as I_o, as will be seen from Figure 3.

If such a transformer core iron is used the magnetizing curve of which shows a pronounced knee, and if the winding turn ratio and the resistor 8 are dimensioned in such a way that the collector saturation current is reached after the core has got into saturation, it will primarily be the peak value of the exciting current which determines the moment of commutation, also when the converter is loaded, however, it being assumed that the primary current of the transformer consists, in the moment of commutation, chiefly of exciting current. Thus the moment of commutation at an inductive load will occur a very short moment earlier than at no-load running. In doubling the battery voltage the commutation will take place as before within half the time. It is evident that the stray field of the transformer between the primary winding 4 and the secondary winding 6, to which the fluorescent tube 7 is directly connected, will react more at a higher frequency caused by an increase of the battery voltage, and vice versa, whereby an automatic control for maintaining a constant load current is attained.

If instead the circuits are dimensioned in such a way that the exciting current will play a smaller part in the moment of commutation, it will be the peak value of the load current that is limited by the collector saturation current. Hence, the commutation will take place as soon as the load current has reached the collector saturation current. In order to make this current and hence the load current practically independent of battery voltage fluctuations the arrangement is so devised that the base emitter current becomes independent of such variations, for instance, by adapting the impedance 8 as a non-linear resistor operating to maintain a constant current. If the load is reactive, the commutation thus occurs earlier the higher the battery voltage is, and as a consequence the current through the fluorescent tube will be almost entirely independent of the variations in the battery voltage. These facts are depicted in Figure 4 which shows that the commutation takes place at the same collector saturation current I_k at varying battery voltage. Conditions intermediating between the cases according to Figures 3 and 4 may of course be applied in practice.

In order to achieve larger power outputs and a symmetrical shape of curve it may be advisable to arrange the inverter in push-pull connection, which does not change anything as regards the principle of the invention. In Figure 5 such a push-pull connected inverter is shown which, in principle, operates in the same manner as the inverter described in connection with Figure 1. As soon as the transistor 3 is choked, due to the fact that the primary current of the transformer has reached the collector saturation current value, the transistor 3' will become conductive, in view of the fact that the voltage in the winding 5' changes sign as soon as the flux in the core starts to fall off. A fully symmetrical alternating potential will therefore be generated in the transformer and the frequency will be proportional to the battery voltage.

As it is possible to attain rather high frequencies by means of such a device, the fluorescent tubes may be ignited without employing a special ignition device, even if the tubes are so called hot cathode tubes, but there is nothing to prevent using the usual ignition devices. For instance, as shown in Figure 5, the secondary winding 6 of the stray field transformer may be provided with two taps to which the filaments of the fluorescent tube are connected. Before the tube is ignited a voltage high enough is generated across the filaments in order to expedite the ignition. The capacitor 9 assists in raising the voltage across 6, before the tube has ignited, whereupon the glow potential of the tube determines the voltage across 6.

A mode of ignition particularly efficient is obtained in an arrangement according to Figure 6. According to the invention the rapid change in primary current occurring at the end respectively the beginning of each pulse (see Figures 2–4) is used for generating high peaks of striking voltage in an auxiliary transformer whose primary winding 10 is connected in series with one or both of the primary windings of the main transformer, and whose secondary winding 11 is connected in series with the winding 6. The winding 11 may also be connected in parallel with the whole winding 6 or a part thereof. By this arrangement the transformation ratio between 4 and 6 may be considerably reduced with an accompanying improvement in efficiency. As the transformer 4, 6 is adapted as a stray field transformer, it is possible in certain cases to omit a special pulse transformer 10, 11 by arranging the winding 10 on the winding 6 of the inverter transformer. In this case the winding 6 will undertake the function of the winding 11.

An advantage of the devices hitherto described resides in the fact that the transistors themselves do not act as current limiters beyond the very moment of commutation, for which reason the losses in the transistors are small and the load capacity of the transistors is large.

In those cases described above, more or less saw-tooth shaped currents are obtained in the fluorescent tube. However, it is possible to cause the current to assume a square shape of curve which results in a higher yield of light in the fluorescent tubes as compared with that obtained with a sinusoidal or saw-tooth shaped current. In this case the limiting of the current through the tubes is not attained by a series inductance but by dimensioning the control circuit of the transistor in such a way that the current obtains a square course. This is most simply carried out by feeding said control circuit from a preconnected oscillator controlled inverter which at the same time operates to maintain a constant current amplitude on the output side. Figure 7 shows by way of example such a device. 14 represents a push-pull connected oscillator operating in the same manner as described in connection with Figure 1 or 5. Through the secondary winding of the transformer 15 the oscillator delivers a square alternating voltage to the control circuit of the inverter 16. The control voltage is maintained constant, for instance by connecting in parallel a voltage dependent resistor 17. The inverter transformer 18 has a leakage as small as possible so as not to affect the shape of curve of the current through the fluorescent tube, which current will depict the control current.

An advantage of the device according to the invention is the fact that the space requirement of the transformer and the other elements is so small that the complete inverter may be assembled with the lamp fittings, in which case the metallic parts of the fittings may be arranged to serve as cooling surfaces for the transistors.

What is claimed is:

1. In combination, a lamp of the type employing an ionizable medium, a transistor inverter, a source of direct current, a stray field transformer having primary winding connections to the transistor inverter and secondary winding connections to said lamp, means in the inverter for automatically varying the frequency of alternating current applied to the transformer substantially proportionally to the voltage variations of the source of direct current comprising, a transistor element having a base electrode, a collector circuit in the inverter including said source of direct current and a primary winding on said transformer, an emitter-base control circuit in the inverter including a potential generating winding on said transformer, a stabilizing resistance connected in said emitter-base control circuit, said transformer having a core and a suitable stray field operatively associated with the secondary winding acting to compensate flux varia-

tions in the transformer core by corresponding frequency variations to maintain the lamp current substantially constant.

2. The combination according to claim 1, in which said transistor circuits are constructed to maintain the collector saturation current greater than the flux saturation current of the transformer core for actual variations of the direct current source voltage.

3. The combination according to claim 2, in which said transformer core has a magnetization curve with a pronounced knee.

4. The combination according to claim 3, in which the stabilizing resistance in the emitter-base control circuit has a fixed value sufficiently high to allow the control current to vary substantially proportionally to voltage generated by the potential generating winding of the control circuit.

5. The combination according to claim 1, in which the stabilizing resistance in the emitter-base control circuit is variable to maintain the collector saturation current substantially constant for actual variations of the direct current source voltage, said transistor circuits being constructed to maintain the collector saturation current below the flux saturation current of the transformer core.

6. A circuit arrangement for energizing a fluorescent lamp with alternating current comprising, in combination with the lamp, a source of direct current, a transistor inverter, a transformer having primary winding connections to the transistor inverter and secondary connections to said lamp, said transistor inverter comprising a transistor element having a base electrode, a collector circuit including said source of direct current and a primary winding on said transformer, an emitter-base control circuit including a potential generating winding on said transformer, and a stabilizing resistance connected in said

emitter-base control circuit, the transistor inverter circuits having electrical values so chosen as to cause the frequency of the transistor inverter to automatically vary substantially proportionally to the voltage of the source of direct current and the lamp circuit having inductance values so chosen as to compensate the frequency variations thereby to maintain the lamp current substantially constant.

References Cited in the file of this patent

UNITED STATES PATENTS

2,016,790	Perlman	Oct. 8, 1935
2,086,668	Fedor	July 13, 1937
2,121,829	Seaman et al.	June 28, 1938
2,300,916	Furedy	Nov. 3, 1942
2,447,304	Atkins	Aug. 17, 1948
2,488,169	Browner	Nov. 15, 1949
2,497,534	Campbell	Feb. 14, 1950
2,681,996	Wallace	June 22, 1954
2,727,146	Fromm	Dec. 13, 1955
2,745,012	Felker	May 8, 1956
2,780,767	Janssen	Feb. 5, 1957
2,816,230	Lindsay	Dec. 10, 1957
2,837,651	Schultz	June 3, 1958

FOREIGN PATENTS

1,123,405	France	June 11, 1956
1,129,507	France	Sept. 10, 1956

OTHER REFERENCES

"Transistor Power Supply," by L. H. Light, Wireless World, December 1955, pages 582 to 586.

"Transistor Power Supply for Geiger Counter," A. R. Pearlman, Electronics, August 1954, pages 144 and 145.