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W. A. DEPP

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RELAXATION OSCILLATOR

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FIG. 1

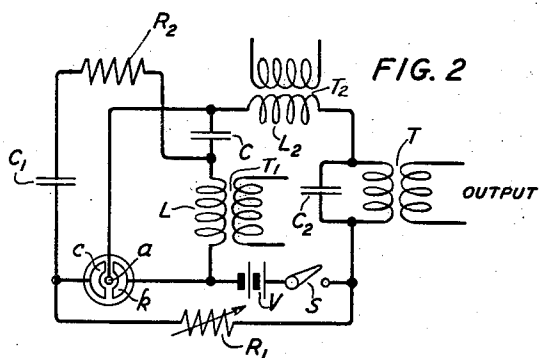
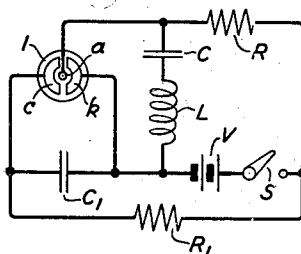


FIG. 3



FIG. 4

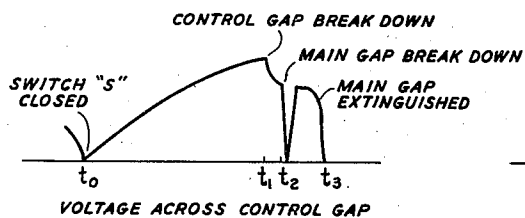
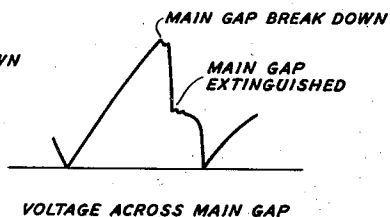


FIG. 5



INVENTOR
W. A. DEPP

BY *A. S. Kugman*
ATTORNEY

UNITED STATES PATENT OFFICE

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RELAXATION OSCILLATOR

Wallace A. Depp, New York, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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2 Claims. (Cl. 250—36)

This invention relates to means for producing alternating current and more particularly to what are called relaxation oscillators which employ so-called gas-filled discharge devices.

Relaxation oscillators employing two-element cold-cathode devices, i. e. having a cathode and an anode, have been known for many years but such arrangements have a low power output and are subject to large changes in frequency due to small variations in the characteristics of the device used.

Since the introduction of the so-called three-element device, which includes a third or control electrode in addition to the anode and cathode, it has been proposed to overcome some of the disadvantages of the two-element arrangement by employing three-element devices, the simplest method being to connect the control electrode to the anode through a current limiting resistance. Since a definite current value is required to flow between the control electrode and cathode before the anode-cathode gap fires, i. e. starts to conduct, it is evident that the voltage, at which the main or anode-cathode gap fires, may be varied by changing the resistance through which the control electrode is connected to the circuit.

While such an arrangement gives an improved control over the frequency and amplitude, it is decidedly limited because the frequency of oscillation is largely dependent upon a definite minimum current (called the transfer current) which must flow in the control gap circuit for a certain main gap potential to cause the main gap to fire and since this minimum value of transfer current will vary in tubes of the same type due to manufacturing variations and will also vary in a given tube due to changes in its characteristics with age, it follows that the frequency and also the amplitude will vary appreciably with any single value of the resistance in the control gap circuit. Obviously it is undesirable to compensate for such changes in transfer current by a more or less continuous readjustment of the resistance referred to and therefore it appears desirable that when the discharge across the control gap is once established the current will rise very rapidly to a value considerably in excess of the predetermined minimum value necessary to fire the main gap which rapid rise is not practicable with arrangements dependent solely on the resistance described.

An object of the present invention is to improve relaxation oscillator circuits of the type employing three-element cold-cathode discharge

devices whereby closer regulation of the frequency and amplitude of the oscillations produced, is secured.

A feature of the invention whereby the above object is obtained resides in the provision of an auxiliary relaxation circuit in association with the control gap in which a condenser is charged to the potential necessary to breakdown the control gap, hence causing ionization, which condenser thereupon discharges across the control gap and causes a rapidly increasing current to flow which will reach and appreciably exceed the desired minimum value necessary to fire the main gap in a much shorter time than in the circuit arrangements heretofore described. By such an arrangement variations in the characteristics of the device employed, which may change the required minimum transfer current to a higher value, will have considerably less effect on the frequency and amplitude of the main gap circuit, than otherwise.

The invention will be understood from the following description when read in connection with the accompanying drawing;

Fig. 1 of which shows the basic circuit of a relaxation oscillator according to the present invention;

Fig. 2 represents a practical circuit of the same type as Fig. 1 but showing means for coupling a work circuit whereby one or both of two characteristic wave forms are derived for use;

Fig. 3 shows a "peaked" wave derived from the inductance L by coupling an output circuit there-to as shown in Fig. 2;

Fig. 4 shows the voltage measured across the control gap (c to k) of Fig. 2 during a complete charge and discharge cycle of condenser C₁; and

Fig. 5 shows the voltage across the main gap of Fig. 2 during a complete charge and discharge cycle of condenser C.

Referring to Fig. 1, the positive pole of a source of direct current, shown as a battery V, is connected by means of a switch S in series with a resistance R₁ to the control electrode c of a three-element cold-cathode gas-filled discharge tube 1, and the cathode k is connected to the negative pole of source V. A condenser C₁ is connected between electrodes c and k, an inductance L and condenser C are connected in series between the anode a and cathode k, and a resistance R is connected between the anode a and the positive pole of the battery V when switch S is closed. When the foregoing connections are made and switch S is closed, a simple relaxation oscillating circuit is established which is well-known in the

art. For the purpose of controlling the breakdown of the space between the control electrode *c* and the cathode *k* a second condenser *C*₁ is connected between them and a second resistance *R*₁ is connected between the positive pole of source *V* and the control electrode *c*.

The operation of the circuit of Fig. 1 is as follows:

Closure of switch *S* completes a charging circuit for condenser *C* in series with inductance *L* and resistance *R*. Condenser *C* soon becomes charged to the potential of source *V*, the time required for this charge being determined mainly by the value of resistance *R*. The potential of source *V* is so chosen that it is sufficiently high to break down the main gap (anode *a* to cathode *k*) when the tube is ionized by a breakdown of the control gap (control electrode *c* to cathode *k*) but insufficient to break down the main gap in the absence of ionization.

Simultaneously with the charging of condenser *C*, condenser *C*₁ starts to charge in series with resistance *R*₁ and when its potential reaches the value required to break down the control gap, a discharge therebetween occurs and current starts to flow which rises very rapidly to a value sufficient to permit the main gap to fire. This current value, i. e., the minimum current sufficient to permit a main gap discharge, is called the "transfer current."

Condenser *C* thereupon discharges across the main gap through inductance *L* and when its potential drops below the value necessary to sustain the main gap discharge, the tube is extinguished. Condenser *C* then starts to recharge from source *V* as before.

In the meantime condenser *C*₁ has discharged across the control gap and lowered its potential below the sustaining voltage of the control gap which has therefore ceased to conduct and this condenser (*C*₁) has, therefore, also started to discharge as before. When it again reaches the control gap breakdown potential it discharges and causes another surge of current to flow which quickly reaches the "transfer current" value and as the values of the main gap circuit are so chosen that by this time the condenser *C* is again charged to the main gap breakdown potential, a second main gap discharge takes place. This sequence of operation is repeated as long as switch *S* is closed.

An improvement in the circuit of Fig. 1 is obtained by substituting a second inductance *L*₂ as shown in Fig. 2 for the resistance *R* shown in the main gap circuit of Fig. 1. The inductance *L*₂ not only increases the efficiency of the arrangement but allows a more stable operation at higher amplitudes. The reason for this is that the condenser *C* charges more slowly in an inductive circuit and there is less chance for the main gap to break down immediately after it has been extinguished and before complete deionization has taken place.

The purpose of inductance *L* in series with condenser *C* of Fig. 1 is twofold. The first is to limit the value of the peak current through the tube when the main gap fires and secondly, to provide more time for the tube to deionize, thereby increasing the upper frequency limit of the oscillator by permitting the condenser *C* to discharge to a value well below the sustaining voltage of the main gap. For the same reason it is advantageous to include inductance in series with condenser *C*₁ and the inductance *L* may be made to serve a dual purpose by connecting con-

denser *C*₁ between the control electrode and the junction of condenser *C* and inductance *L* as shown in Fig. 2.

Referring to Fig. 2 the condenser *C*₁ charges up as before through *R*₁, *R*₂ and *L* and then discharges through *L*, *R*₂ and the control gap. Before this discharge is complete the main gap discharge takes place and the voltage across *L* due to this has a form as shown in Fig. 3. The negative peak is due to the establishment of current flow in the tube while the smaller positive peak is due to the cessation of current flow. This voltage is conveyed to the control gap through *C*₁ and the resultant wave form of the voltage across the control gap as observed on a cathode-ray oscillograph is shown in Fig. 4. During the period *t*₀ to *t*=*t*₁ the condenser *C*₁ is charging exponentially through *R*₁, *R*₂ and *L*. At *t*₁ the breakdown voltage of the control gap is reached whereupon a discharge starts and at *t*₂ the discharge in the main gap begins. Shortly before *t*₃ the main gap is extinguished, the voltage across *L* falls to zero, the discharge of *C*₁ through the control gap and *L* is continued until the control gap extinguishes and by *t*=*t*₃ the control gap voltage has become equal to the condenser voltage. This latter voltage depends upon the circuit constants but is often near zero as shown. By this arrangement the discharges in the two gaps are "synchronized" since the voltage across the control gap cannot build up again until the main gap discharge has been completed. By varying resistance *R*₁ the frequency of the oscillations can be regulated over a wide range. The value of resistance *R*₂ may be so chosen as to limit any reverse current caused by inductance *L* which would tend to make the control anode a cathode during part of a cycle.

In order to utilize the oscillations provided in the arrangement of Fig. 2, *L* and *L*₂ may form the primaries of transformers *T*₁ and *T*₂, respectively, the secondaries of which may be connected to load circuit. From the secondary of *T*₁ a voltage of the form shown by Fig. 3 is obtained while from *T*₂ a voltage is obtained which is the alternating current component of the main gap voltage as shown in Fig. 5.

A substantially sinusoidal wave is obtained from the transformer *T* of Fig. 2 in which the main gap voltage wave is approximately the same as Fig. 5 but most of the fundamental frequency of this voltage appears across the tuned circuit consisting of condenser *C*₂ and the primary winding of transformer *T* while most of the harmonics appear across *L*₂.

The circuit of Fig. 2 is capable of carrying a much greater load than previous oscillators employing two-element tubes as the condenser *C* may be allowed to charge up to a value above the battery voltage and to discharge to a value near zero each cycle, the only precaution necessary being to see that the peak current rating of the tube used is not exceeded since the circuit continues to operate even through the tube is badly overloaded.

A further advantage of the present arrangement is the lack of dependence of the frequency on small changes in the characteristics of the tube which may change the value of the transfer current.

In the arrangement shown and described, due to the fact that when the condenser *C*₁ discharges across the control gap, a surge of current ensuing which rises very rapidly to a value substantially greater than the value of the current nec-

essary to cause the main gap to fire, therefore small variations in the tube characteristic which may increase the current required for a main gap discharge will have little or no effect on the frequency.

What is claimed is:

1. In a relaxation oscillator, a gas-filled tube comprising an anode, a cathode and a control electrode, a source of direct current, a main relaxation oscillator circuit comprising said source connected between said anode and cathode and a first condenser and an inductance serially connected in parallel with said anode and cathode, and means for controlling the frequency of said main circuit comprising a second relaxation oscillator circuit serially including said source, a resistance, and a second condenser, said cathode and control electrode being connected in shunt to said second condenser.

2. In a system for converting direct current to alternating current, the combination with a source of direct current and a gas-filled discharge device having an anode, a cathode and a control electrode, of a main relaxation oscillator circuit comprising said source connected between said anode and said cathode, and a first condenser and an inductance in series connected between said anode and cathode, and means for controlling said main oscillator circuit comprising a second relaxation circuit serially including said source, cathode and control electrode and a second condenser in series with said inductance connected between said cathode and control electrode.

WALLACE A. DEPP.