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2,373,223

CRYSTAL CONTROLLED RELAXATION OSCILLATOR

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Fig. 1.

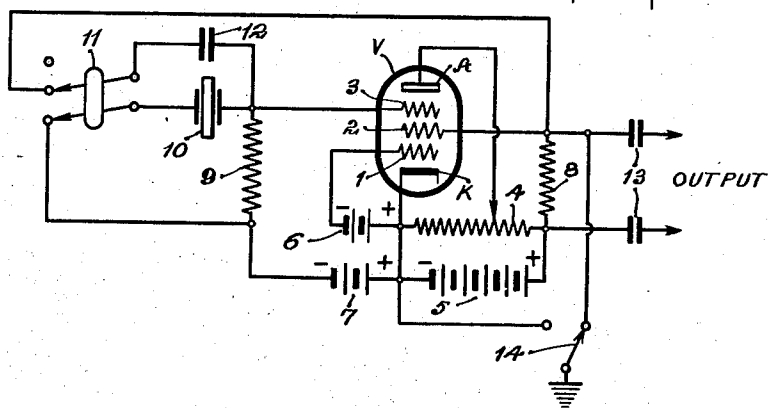


Fig. 2.

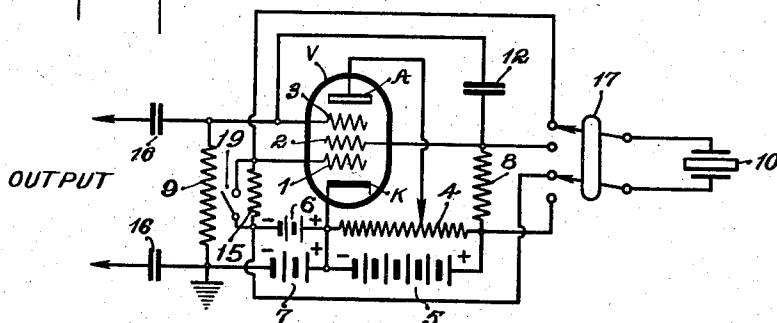
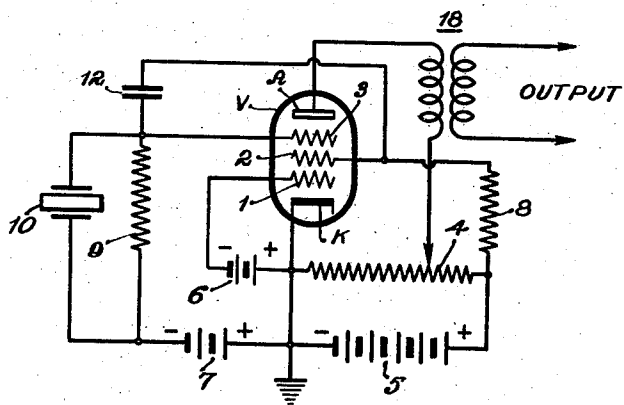


Fig. 3.



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CRYSTAL-CONTROLLED RELAXATION
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Application January 27, 1943, Serial No. 473,671

1 Claim. (Cl. 250—36)

This invention relates to crystal-controlled relaxation oscillators.

I am well aware that piezo-electric elements have been used in the past for controlling the frequency of various forms of oscillation generators.

It is, however, an object of the present invention to provide an improved crystal-controlled relaxation oscillator having circuit arrangements such that the frequency shall be stabilized in a high degree.

It is another object of my invention to provide a single tube generator which may be used under certain conditions as a substitute for the well-known double-tube multivibrator circuit.

In my Patent No. 2,070,647, a multivibrator circuit was shown which accomplished results similar to those for which the instant invention is intended. As will be developed in the description to follow, it will be seen that the present invention offers many advantages over the system of the well-known multivibrator.

In some respects, furthermore, the present invention is an improvement upon relaxation oscillators of the tetrode type such as illustrated by my Patent No. 2,058,559.

The basic principle involved in the present circuit arrangements is one where oscillations are produced by operating the tube in such manner that it exhibits a negative transconductance characteristic. This is done without the aid of secondary emission. An oscillation generator is, therefore, produced having more reliable operating characteristics than was heretofore possible.

My invention will now be described in more detail, reference being made to the accompanying drawing, in which:

Fig. 1 shows diagrammatically a circuit arrangement which may be operated in either of two or more different ways depending upon the setting of double-throw switches as shown;

Fig. 2 shows a modification of the circuit arrangement of Fig. 1, a feature being the coupling arrangements for the output circuit; and

Fig. 3 shows still another modification of the invention in which the crystal control is applied between the cathode and the grid nearest the anode, and the output circuit is inductively coupled to the anode circuit.

Referring first to Fig. 1, I show an electron discharge tube V having a cathode K, an anode A, and three grids 1, 2, and 3. A potentiometer 4 is connected across the terminals of the direct current source 5. The first grid 1 is negatively

biased with respect to the cathode K by means of the battery 6. The grid 2 is maintained at the most positive potential, being connected to the positive terminal of the source 5 through the resistor 8. The anode A is maintained at a less positive potential, connection being made to a suitable point on the potentiometer 4. The grid 3 is connected to the cathode K through a resistor 9 and the battery 7 which maintains this grid at a negative potential.

A piezo-electric element 10 is arranged to connect in shunt with resistor 9, or, alternatively, between grids 2 and 3. These alternative connections are rendered possible by the use of a double-pole double-throw switch 11. When the piezo-electric element 10 is connected in shunt with resistor 9, then it is necessary to intercouple the grids 2 and 3 by means of a capacitor 12. This arrangement is effective when the switch 11 is set in the position shown. When the switch 11, however, is thrown to the alternative position, the piezo-electric element 10 takes the place of capacitor 12.

The output circuit, or utilization device, may be coupled across the resistor 8 by means of capacitors 13. The single-pole double-throw switch 14 has its movable contact member grounded and is provided for grounding either the cathode or the second grid 2 according to the external circuit requirements.

The operation of the generator as shown in Fig. 1 is as follows:

Assume for the moment that the piezo-electric element 10 is omitted from the circuit. Grid 3 is used as the control electrode. If it is made negative, part of the electron stream between cathode and anode will be repelled, causing a decrease in the anode current. The repelled electrons are attached to the positively charged grid 2, and this results in an increase in the current drawn by grid 2. The resulting effect is a negative transconductance characteristic between the grids 3 and 2, and the circuit of grid 2 exhibits a negative resistance.

Assume now that, due to some disturbance, there is a minute decrease in the voltage of grid 3. This causes an increase in the current in the circuit of grid 2 with a resulting increase in potential drop across resistor 8. The potential of grid 2 is thus decreased somewhat. This change of potential acting through condenser 12 causes a decrease in the potential of grid 3. A corresponding decrease of potential of grid 2 then takes place making grid 3 still less positive. This cycle of events continues until the potential of the grid

3 becomes so low that the cut-off point is reached. Thus all the electrons from the cathode are absorbed by grid 2 and no current reaches the anode A. Any further decrease of potential of grid 3 has no effect on the electron stream within the tube. Condenser 12 now begins to discharge through resistors 8 and 9. During the discharge period, the potential on grid 3 increases. The cycle of events described is now repeated but in the opposite direction. Grid 3 becomes more and more positive until saturation is reached and no further increase in anode current can take place. The current drawn by grid 2 is then reduced to a minimum. The condenser 12 will now discharge in the opposite direction and the cycle of events will be repeated. The alternate discharges of the condenser will continue as long as energy is supplied from the sources 5, 6, and 7. A series of aperiodic pulses of potential occurring in cyclic order will thus be obtained, the frequency of recurrence of the relaxations being determined by the values of the capacitor 12 and of the resistors 8 and 9.

Without the piezo-electric crystal 10, the operation of the circuit arrangement as above described is apt to be quite erratic. There is no frequency stabilization. A relaxation oscillator is, however, quite sensitive to applied periodic voltages of suitable frequency, as is well known. A control frequency of very small amplitude is found to be sufficient for maintenance of a constant frequency of oscillation. Not only may a fundamental control frequency be applied, but a harmonic relation may be maintained between the control frequency and the frequency of the generator. In any event the system can be locked in step with the applied voltage and the generated frequency will be dependably controlled thereby.

The function of the piezo-electric crystal 10 is, therefore, to apply the necessary stabilizing force for controlling the frequency of the generator. When the crystal 10 is connected across the resistor 9, an alternating voltage corresponding to the potential of grid 2 is applied to the crystal electrodes. If the circuit is adjusted so that its frequency is the same, or very nearly the same, as the resonant frequency of the crystal, then the crystal will be set in vibration, and, due to the piezo-electric action, a voltage will be applied to grid 3 which is very nearly in phase with the potential of grid 2, and of sufficient amplitude to pull the oscillator in step, after which it will remain locked in step. The circuit may, of course, be adjusted to a sub-harmonic or a harmonic of the crystal frequency and will be controlled thereby.

Referring now to Fig. 2, I show therein a modification in which the same tube V is used. Furthermore, this tube preferably possesses the same electrodes as those of the tube V in Fig. 1. Accordingly, like reference characters are applied to like parts in different figures of the drawing.

In Fig. 2 a resistor 15 is shown connected between the source 6 and the grid 1. The capacitor 12 is at all times connected between grids 2 and 3. The piezo-electric element 10 is arranged to be connected either in shunt with resistor 15 or in shunt with resistor 8 depending upon the position in which the double-pole double-throw switch 17 is set. When the switch 17 is set in the position connecting the piezo-electric element in shunt with resistor 8 the switch 19 may be used to short the resistor 15.

The output circuit is preferably coupled across

resistor 9 by means of capacitors 16. A ground connection may be made to the negative terminal of the source 7 as shown, or, if desired, the cathode K may be grounded.

When the piezo-electric element is in shunt with resistor 8, the circuit arrangement of Fig. 2 operates in very much the same manner as that of Fig. 1, and no further description of operation is necessary.

When the piezo-electric device is in shunt with resistor 15, the alternating voltage impulses appearing across resistor 15 excite the crystal 10, which then controls the frequency of oscillation.

In Fig. 3 I again show a discharge tube V, the electrodes of which may be the same as shown in the other figures. These electrodes are, therefore, given like reference characters. In Fig. 3 the anode circuit includes a primary winding of a transformer 18. The secondary of this transformer may be used to develop an output potential for serving any desired utilization device.

In Fig. 3 the piezo-electric element 10 is shown connected permanently in shunt with resistor 9. The capacitor 12 is also permanently connected between grids 2 and 3. In other respects, the similarities between the circuit arrangement of Fig. 3 and of Figs. 1 or 2 will be recognized by those skilled in the art, so that the operation of this circuit will be well understood in view of the foregoing description.

It should be noted that the use of grid 1 is more or less optional since it is possible to construct and operate a relaxation oscillator in accordance with my invention, while eliminating the grid 1 altogether. The amplitude of the oscillations generated is, however, subject to control by the bias applied to grid 1 and for this reason the use of a pentode rather than a tetrode tube is preferred.

The constants of the oscillating system described herein may be made such that oscillations are obtained which are not strictly of the relaxation type. The device then functions somewhat differently. However, since the circuit remains the same in appearance, such an arrangement will be described here. Referring to Fig. 3, consider capacitor 12 to be made small enough so that the system will not oscillate of itself. When the crystal 10 is connected in the circuit, the system will oscillate at the frequency of the crystal. The capacitor 12 in this case functions merely as a coupling capacity to feed energy from grid 2 back to grid 3 in the proper phase to sustain the vibrations of the crystal. An alternative use for the circuit arrangement of Fig. 3 is thus provided which extends beyond the scope of relaxation type oscillators.

In the conventional showing of the cathode in each of the figures, it would appear that tubes of the indirectly heated cathode type are preferable. It will be understood, however, that the invention is not limited to the use of such tubes. A tube with a directly heated filament type cathode can be used just as well.

It is not necessary to ground the system exactly as shown in the different circuit arrangements, nor is grounding necessary for proper operation. It should be further understood that when grounding is desired or necessary for certain applications of the device, the ground connection may be made at any point in the circuit.

Features of one figure may be combined with those of another figure without departing from the spirit of my invention. Any satisfactory method of coupling to an external circuit may be

used including that form known as electron coupling. Furthermore, it may be desirable in certain instances to employ a tube having additional electrodes such as a hexode or other multigrid tube.

My invention is capable of modification in other ways as may well be understood by those skilled in the art.

I claim:

An oscillation generator comprising a discharge tube having a cathode, a first grid, a second grid and a third grid disposed in the electron path in the order named, and an anode, a capacitive circuit regeneratively interconnecting the second and third grids, means including independent circuits for maintaining a negative bias

on the first and third grids with respect to the cathode, each of said independent circuits having a separate biasing source connected therein, and the circuit connection between the cathode and first grid being arranged and adapted to automatically control the amplitude of the oscillations generated, a direct current source connected between the cathode and the second grid, also between the cathode and anode, said source connections being substantially non-reactive and of such impedance values that the second grid is more positive than the anode, and piezo-electric means interconnecting two of the electrodes of said tube in such manner as to fix the generated frequency.

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