Oct. 27, 1936. A. M. BRAATEN 2,058,559

CONSTANT FREQUENCY OSCILLATION GENERATOR

Filed March 30, 1933

Fig. 2

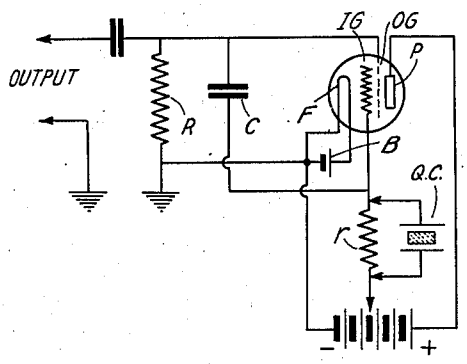


Fig. 3

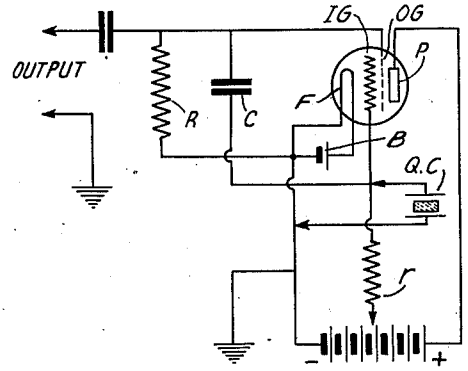


Fig. 4

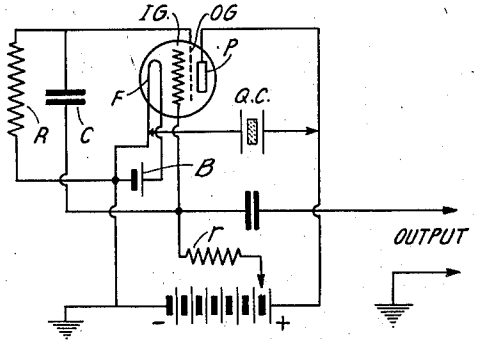


Fig. 5

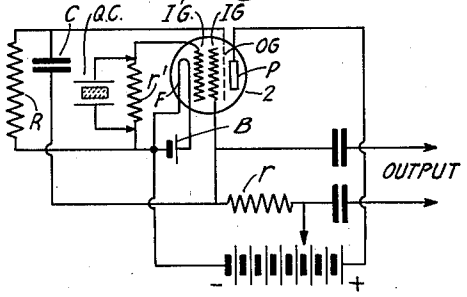
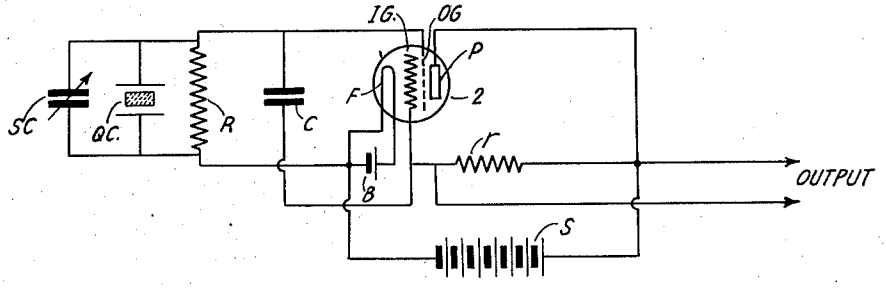


Fig. 1



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CONSTANT FREQUENCY OSCILLATION GENERATOR

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9 Claims. (Cl. 250—36)

This invention relates to electrical oscillation generators of the multi-vibrator type. The principal object of my present invention is to provide improved circuits of the multi-electrode relaxation oscillator type wherein the frequency of oscillation is maintained constant by the use of an electromechanical vibrator preferably in the form of a piezo-electric crystal.

Briefly, my invention contemplates the use of a multi-electrode tube whose electrodes are so interconnected by means of resistors and condensers as to set up relaxation oscillations. It further contemplates the interconnection of a piezo-electric crystal in such a way with the circuits and elements of the oscillation generator as to maintain the relaxation oscillations constant in frequency.

My invention is defined with particularity in the appended claims. However, it may best be understood both as to its structural organization and mode of operation by referring to the accompanying drawing wherein

Figure 1 illustrates one form of my improved crystal controlled relaxation oscillation generator wherein a frequency stabilizing crystal is connected to a resistance connected between the outer grid and cathode of a multi-electrode relaxation oscillation generator;

Figure 2 is an arrangement similar to Figure 1 wherein the stabilizing crystal is connected to a resistance connected between the inner grid and cathode of a multi-electrode relaxation oscillation generator;

Figure 3 illustrates a further modification wherein a piezo-electric crystal is connected between the inner grid and cathode of a multi-electrode relaxation oscillation generator;

Figure 4 illustrates still another modification wherein the frequency stabilizing crystal is connected between the cathode and plate of a multi-electrode relaxation oscillation generator; and,

Figure 5 illustrates still another modification of my present invention utilizing a multi-electrode tube having a space charge grid.

Referring to Figure 1, an electron discharge device 2 preferably in the form of a vacuum tube, is provided with a filament F, an inner grid IG, an outer grid OG and a plate P. A source of potential S is used to supply plate potential and the filament is energized by means of another source of potential in the form of a battery B. Resistors R and *r* are connected respectively between the outer grid OG and the filament or cathode F and between the plate P and inner grid IG. A condenser C is connected between the outer grid OG and the inner grid IG.

As so far described, relaxation oscillations will be set up. In other words, there will occur aperiodic pulses of potential in cyclic order causing an output which is very rich in harmonics and incidentally quite unstable in frequency.

To explain the operation in greater detail, and as illustrated in the circuit of Figure 1, but without the crystal, oscillations are generated continuously on saturation current within the tube, the saturation current being considered the sum of the plate, outer grid, and inner grid currents. An increase in plate current causes a decrease in inner grid current, and vice versa. With no current flowing through R, the outer grid is at the same potential as the cathode. Suppose now that in some manner a positive potential is put on the inner grid. The condenser current through R, resulting from the potential across C, increases the potential of the outer grid. The corresponding increase in plate current is accompanied by a decrease in the inner grid current, which still further increases the potential on the inner grid, due to the current through *r*. More current from the increased charge on C operates to still further reduce the inner grid current. The charging current through R causes a very high potential on the outer grid. As the condenser becomes charged and the current through R decreases, the outer grid potential decreases, approaching the potential of the cathode. When the outer grid potential reaches the value at which the plate current is reduced, the inner grid current begins to increase. The inner grid potential is decreased and current from C begins to flow through R in the opposite direction. The potential of the outer grid goes negative causing a further reduction in the inner grid potential. The high negative potential on the outer grid will decrease as the discharge current from C decreases. When the outer grid potential reaches the value at which plate current beings to flow, the inner grid current is decreased. The outer grid potential will increase as explained before. The complete cycle of events, causing the condenser to charge first in one direction and then in the other, will continue as long as energy is supplied to the system from the battery sources which of course may be replaced by rectifiers or generators. The frequency of the oscillations can be controlled by varying the values of either the condenser or the resistors, or both.

In the preferred form of my invention, the circuit such as that shown in Figure 1 is adjusted

so that the frequency of oscillation is the same or very nearly the same as the resonant or natural frequency of the piezo-electric quartz crystal QC. By connecting the quartz crystal QC across the resistor R as shown in Figure 1, an alternating voltage corresponding to the potential across R is applied to the crystal electrodes. Consequently the crystal is set into vibration, and due to piezo-electric action, applies a voltage to the outer grid which is very nearly in phase with the potential variations across the resistor R. I have found that the frequency of oscillation of the relaxation oscillator is readily influenced by the small voltage applied by the crystal as a result of which the system is locked into step with the crystal frequency and consequently the frequency of oscillation generated thereby is exceedingly constant.

In the arrangement shown in Figure 2 the crystal is connected across the resistor *r*, frequency stabilizing action being as before. In Figure 3, the crystal is connected between the inner grid and the filament whereby potential variations of the inner grid are applied to the crystal electrodes. In Figure 4, the crystal or frequency controlling element or electromechanical vibrator is connected between the plate and filament or cathode as a result of which the alternating plate potential is applied to the crystal.

Figure 5 illustrates a further modification wherein the quartz crystal QC is connected across the resistor *r'* in turn connected between the space charge grid I'G and the cathode F. The other electrodes are connected as before. If desired, the tube **2** of Figure 5 may be of the pentode type in which case I'G would be the usual control grid, IG the screen grid, and OG the suppressor grid of the tube **2**.

In any of the above modifications, a small condenser SC may be connected across the piezo-electric crystal electrodes for obtaining fine variations in frequency of vibration. Also, the various cathodes need not be of the D. C. energized type as illustrated, but may be of the indirectly heated type wherein the heating element may be supplied with alternating heating currents. Moreover, although it is preferred that the cathode be grounded, any other single one of the electrodes of each modification may be grounded as found desirable.

The constant frequency oscillations generated by the various circuits may, of course, be used in frequency determination systems, for the purpose of controlling the frequency of a radio transmitter, or in a radio receiver of the superheterodyne type. Also, it is to be borne in mind that while it is desirable to make the frequency of relaxation oscillation equal that of the piezo-electric crystal, it will be found that the system will work and maintain constant frequency oscillation generation when the relaxation circuits comprising the condenser and resistances are so adjusted as to produce relaxation oscillations at some sub-multiple frequency of the piezo-electric crystal. In other words, the crystal will oscillate at some harmonic of the relaxation oscillation frequency but despite that will maintain the large valued relaxation oscillations of constant frequency.

Having thus described my invention, what I claim is:

1. Oscillatory apparatus comprising a vacuum tube having a cathode, an anode, a grid adjacent the cathode, a grid adjacent the anode, and a grid intermediate said grids, a non-inductive circuit connected between the grid adjacent said cathode and said cathode, a resistor shunted by a piezo-electric device constituting at least a portion of said non-inductive circuit, a second resistor connected between the grid adjacent said anode and said cathode, a condenser connected between the grid adjacent said anode and said intermediate grid, a third resistor connected between said intermediate grid and said anode, and a source of potential connected between said anode and cathode.

2. A constant frequency relaxation oscillation generator comprising an electron discharge device having an anode, a cathode, an inner grid and an outer grid, a resistor connected between said outer grid and said cathode, a polarizing circuit connected between said cathode and said anode, a non-inductive circuit including a second resistor connected between said inner grid and a point on said polarizing circuit, a condenser connected between said outer grid and said inner grid, and, a piezo-electric crystal connected in shunt with one of said resistors, the values of said resistors and condenser being so chosen that relaxation oscillations are produced at a frequency substantially equal to some sub-multiple of a natural frequency of said piezo-electric crystal.

3. Apparatus as claimed in claim 2 wherein said piezo-electric crystal is connected across the resistor connected between said outer grid and said cathode.

4. Apparatus as claimed in claim 2 wherein said piezo-electric crystal is connected across the resistor connected between said inner grid and a point on said polarizing circuit.

5. In an oscillation generator of a multivibrator type, an electron discharge tube having a cathode, an anode electrode, and a plurality of screen electrodes progressively spaced between said cathode and said anode electrode, a non-inductive impedance circuit interconnecting the cathode and the screen electrode nearest the anode, a circuit including a direct current source interconnecting the cathode and the anode electrode, a second non-inductive impedance circuit interconnecting a point on the last named circuit and the screen electrode nearest the cathode, a capacitive circuit interconnecting two of said screen electrodes, and means including a piezo-electric device having at most two electrodes connected one to the cathode and the other to one of the other tube electrodes for stabilizing the frequency of the oscillations generated.

6. An oscillation generator according to claim 5 and having the values of said impedance circuits and of said capacitive circuit so chosen as to produce relaxation oscillations at a frequency to which the working frequency of said piezo-electric device is harmonically related.

7. In an oscillation generator of the multivibrator type, an electron discharge tube having a cathode, an anode electrode, and a plurality of screen electrodes progressively spaced between said cathode and said anode electrode, a non-inductive impedance circuit interconnecting the cathode and the screen electrode nearest the anode, a circuit including a direct current source interconnecting the cathode and the anode electrode, a second non-inductive impedance circuit interconnecting a point on the last named circuit and the screen electrode nearest the cathode, a capacitive circuit interconnecting two of said screen electrodes, and means including a piezo-electric device having at most two electrodes con-

nected one to a point in circuit with the cathode and the other to one of the other tube electrodes, for stabilizing the frequency of the oscillations generated.

8. A constant frequency relaxation oscillation generator comprising an electron discharge device having an anode, a cathode, an inner grid and an outer grid, a resistor and a piezo-electric device connected in parallel between said outer grid and said cathode, a second resistor connected between said inner grid and said anode, and a capacitor connected between the two said grids.

9. A constant frequency relaxation oscillation generator comprising an electron discharge device having an anode, a cathode, an inner grid and an outer grid, a resistor connected between said outer grid and said cathode, a second resistor and a piezo-electric device connected in parallel between said inner grid and a point in circuit between said cathode and anode, and a capacitor connected between the two said grids.

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