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R. A. HEISING

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CRYSTAL CONTROLLED OSCILLATOR

Filed July 25, 1927

FIG. 1

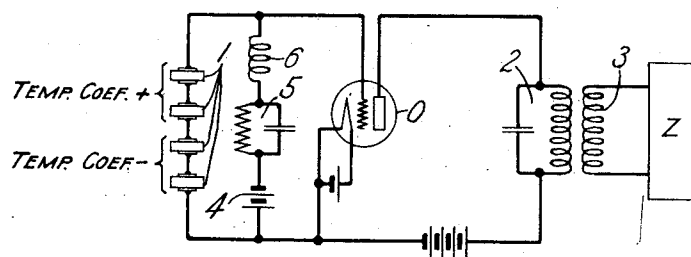
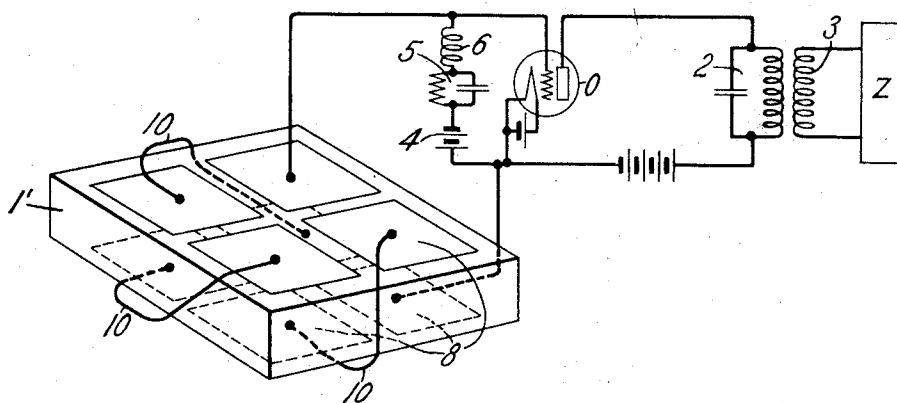


FIG. 2



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CRYSTAL-CONTROLLED OSCILLATOR

Application filed July 25, 1927. Serial No. 208,225.

This invention relates to control of operation of electric circuits, and especially to frequency control of oscillators by piezo-electric crystals.

An object of the invention is to increase the amount of power that can be conveniently controlled by a piezo-electric element.

In one specific aspect, the invention is a crystal controlled electric space discharge tube oscillator in which the controlling crystal has a plurality of pairs of opposed metallic plates so connected electrically as to produce in effect a plurality of series connected crystals among which the total voltage applied to the crystal is divided, so that the voltage across the part of the crystal separating any two opposing plates is but a portion of the total voltage. As a result, the plate voltage of the oscillator tube, and consequently, the power output of the oscillator, can be greatly increased without danger to the crystal. It is not necessary that the sections of the crystal between the respective pairs of plates be absolutely identical, in order to have all of the sections operate as one crystal at one frequency.

Other objects and aspects of the invention will be apparent from the following description and claims:

Fig. 1 is a diagram of an oscillator having separate series connected control crystals in accordance with the invention; and

Fig. 2 is a diagram of a form of the invention having a control crystal with series connected sections, the crystal being shown in perspective.

The vacuum tube oscillator in Fig. 1 comprises a three electrode space discharge tube 0 with an input circuit including four piezo-electric crystals 1 connected in series, and with a tuned plate circuit 2. It is not necessary that the plate circuit be tuned. A suitable coil alone might replace the condenser and coil comprised in the tuned circuit 2. Preferably the crystals have the same fundamental frequency or very nearly the same frequency. However, it is not necessary that the crystals be of the same frequency, fundamentally. For example, the fundamental frequency of one may be a sub-multiple, such

as $\frac{1}{3}$ or $\frac{1}{5}$ etc., of the natural vibration frequency of the others. The operating frequency is not the resonant frequency but is near it, and the combined reactance of all of the crystals is an inductance, say L_1 .

A source of negative grid potential 4, a condenser and grid leak resistance 5, and a choke coil 6 are shown connected across the grid and filament for supplying biasing potential to the grid. Any of these grid biasing elements, or combinations of them, may be used to properly bias the grid. When the choke coil is not used, the by pass condenser across the resistance is also not used.

The plate circuit 2 coupled by coil 3 to load circuit Z of any desired type operates at such a frequency as to have an inductive reactance, say L_2 . L_1 and L_2 together with the grid-to-plate capacity form a tuned circuit. Thus, the oscillator is of the well known Hartley type. When the tube is delivering its maximum power there will be a certain alternating plate voltage E_p between the plate and filament. This voltage will occur when delivering this amount of power regardless of the magnitudes of L_1 and L_2 . When the given L_2 and grid-plate capacity, the grid circuit inductance L_1 will also be determined. Under maximum power conditions there is usually obtained a fixed E_g or alternating grid filament voltage. If instead of the series connected crystals 1, a single crystal were employed as usual, this voltage E_g occurring across the crystal would give trouble when it reached certain values ordinarily in the neighborhood of a few hundred volts. Connecting the four crystals 1 in series is a method of reducing the voltage across each crystal used. If these crystals are identical only a quarter of the voltage E_g occurs across each, and the value to which it is possible to raise the plate voltage on the oscillator tube before a dangerous voltage across each crystal is reached is approximately four times as high as if a single crystal were used. Consequently, much more power can be secured from the controlled oscillator.

To reduce undesired variations in the frequency of the controlled oscillator due to

temperature changes, part of the crystals may have temperature of coefficients of frequency opposite in sign to those of the remainder of the crystals. For example, two of the crystals in Fig. 1 may be quartz crystals cut perpendicular to a natural face of the whole crystal and the remaining two may be cut parallel to a natural face, since crystals cut perpendicular to a natural face usually have temperature coefficients opposite in sign to those of crystals cut parallel to a natural face, though not always so. Crystals cut similarly sometimes have opposite temperature coefficients so that the combinations of crystals to use depend only on the sign of the temperature coefficient and the magnitudes. The algebraic sum of all the coefficients should approach zero.

The difficulty of making the four crystals identical is avoided in Fig. 2, by, in effect, mechanically coupling the four crystals together; for in Fig. 2 there is employed a single large crystal 1' of four times the area of each of the crystals of Fig. 1 and each of four quarters or sections of the large crystal is included between a pair of opposing metallic plates 8 individual to the section, the lower plate of one pair being connected to the upper plate of another, as indicated by conductors 10 in Fig. 2, until the four parts of the crystal are in series. The series of sections is connected in the grid circuit in the same manner as the series of crystals in Fig. 1. Even though the four sections in Fig. 2 are not absolutely identical all four quarters will operate as one crystal at one frequency.

It will be understood that a square crystal as shown is not essential, as the crystal might be of other shapes, as for example oblong or circular. The arrangement of plates on the crystal can be other than that shown, as for example, a linearly extending sequence of plates from one end to the other end so as to reduce capacity between extreme plates. The number of plates preferred will depend on the voltage requirements. This crystal combination can be placed in any circuit position suitable for controlling operation of a circuit, as for example, in any of the positions in which crystals are customarily employed in the various crystal oscillator circuits in use.

What is claimed is:

1. A wave translating system comprising a piezo-electric crystal device adapted to elastically vibrate as one crystal at one frequency, pairs of electrodes for said device, a different portion of said device being interposed between each pair of said electrodes, and means including said electrodes for connecting said portions in series with each other.

2. In a frequency selective amplifying circuit, the combination with wave amplifying means of means for fixing the frequency se-

lectivity of a part of the circuit, and a crystal device included in said second means adapted to elastically vibrate as a unit with the natural period determined by the crystal mass as a whole, said crystal device comprising pairs of electrodes, and means connecting portions of said crystal device in series with each other, each of said portions being interposed between a different pair of said electrodes.

3. An oscillator comprising a single crystal body for setting the oscillator frequency, a plurality of pairs of plates associated with said body, and means connecting successive pairs of said plates in series with each other whereby the overall voltage applied to the plates is divided between the sections of the crystal body between the respective pairs of plates.

4. An oscillator comprising an electric space discharge device having an input circuit and an output circuit, a single crystal body having associated therewith a plurality of pairs of electrically conducting plates so connected to each other and to said input circuit as to produce in effect a plurality of series connected crystals among which voltage due to energy fed from said output circuit to said input circuit is divided, whereby said crystal body may control oscillations of high power without danger of injuring said crystal body.

In witness whereof, I hereunto subscribe my name this 22 day of July A. D., 1927.

RAYMOND A. HEISING.