

April 29, 1941.

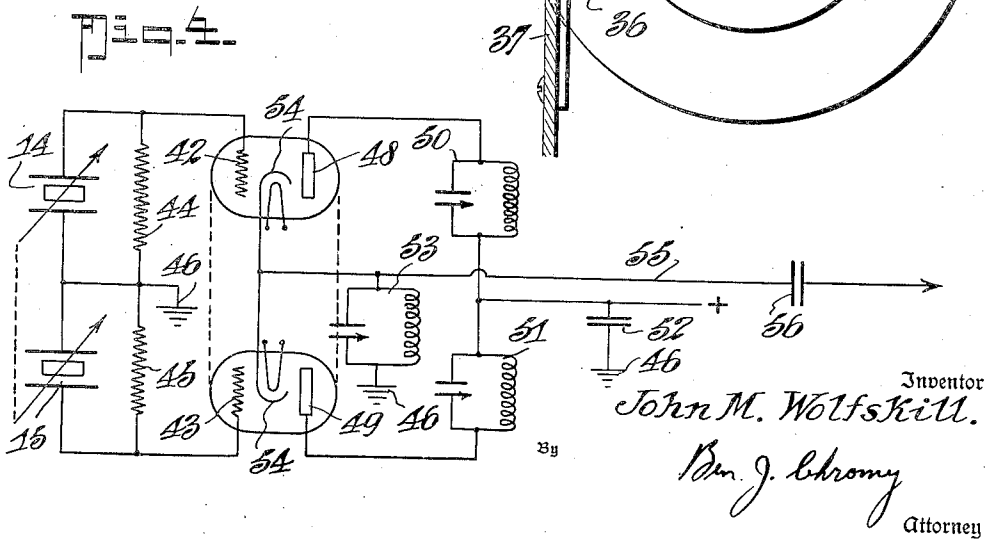
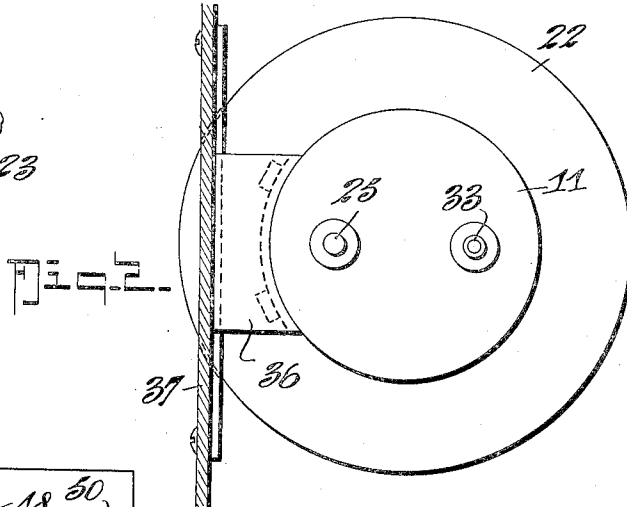
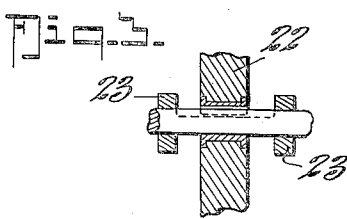
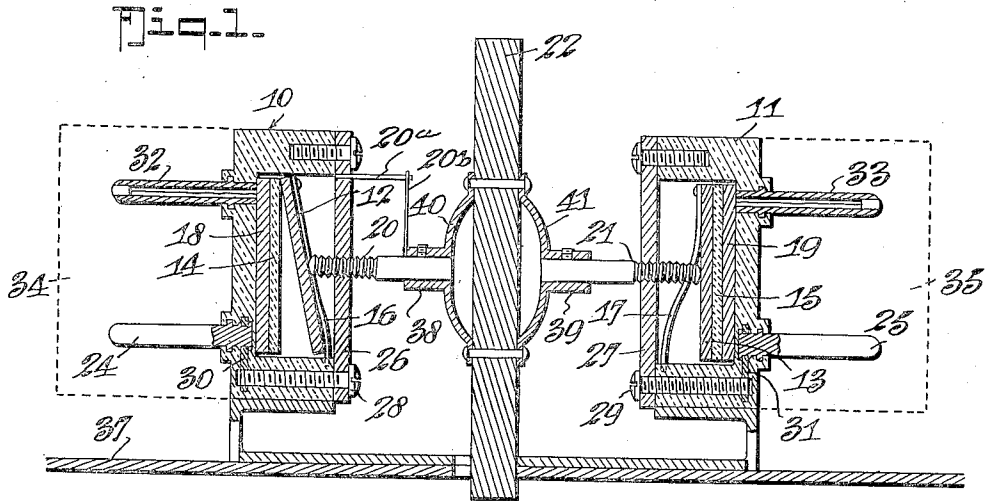
J. M. WOLFSKILL

2,240,452

PIEZOELECTRIC CRYSTAL APPARATUS

Filed May 23, 1940

2 Sheets-Sheet 1



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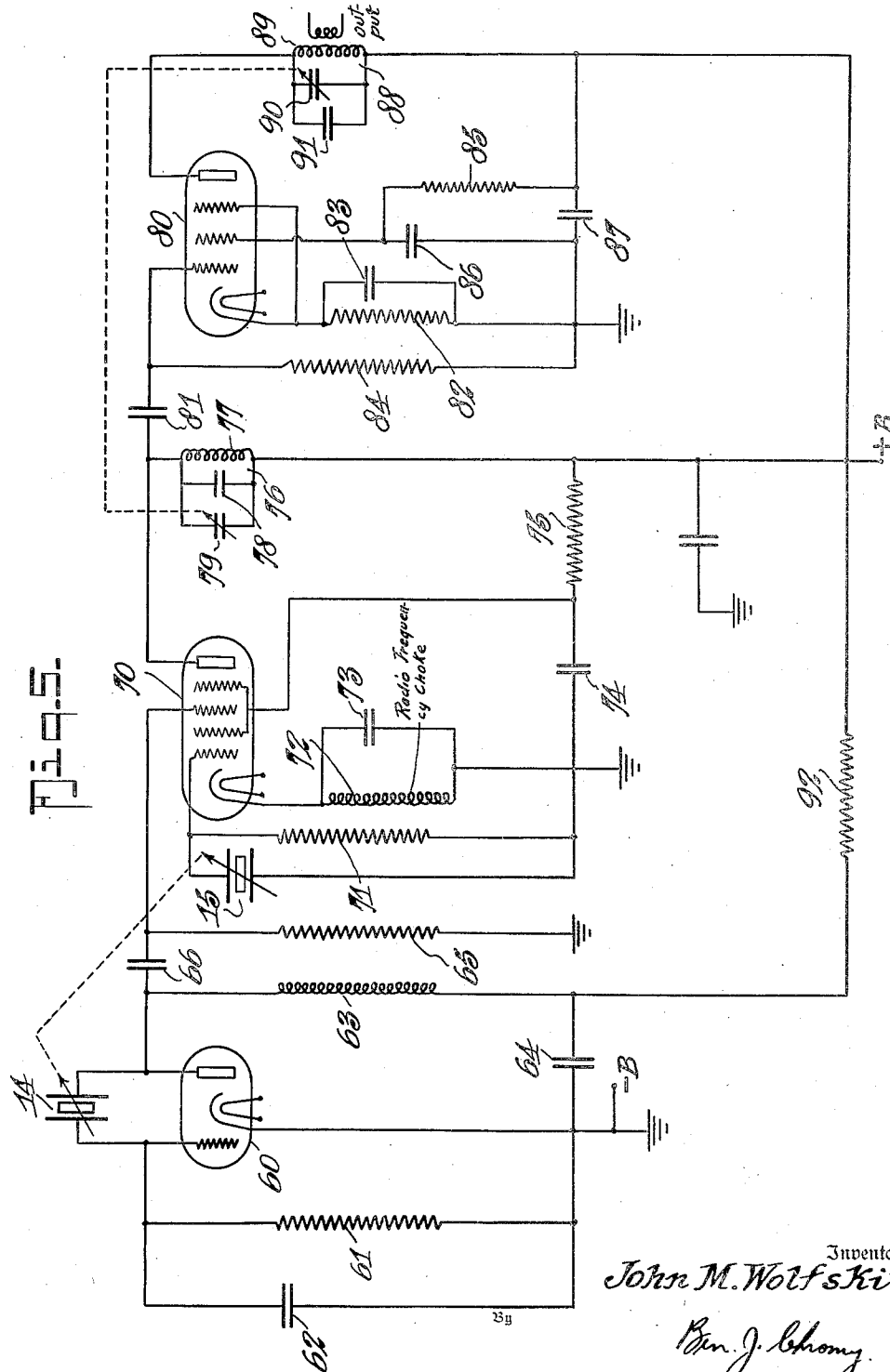
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PIEZOELECTRIC CRYSTAL APPARATUS

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2 Sheets-Sheet 2



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PIEZOELECTRIC CRYSTAL APPARATUS

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Application May 28, 1940, Serial No. 337,698

13 Claims. (Cl. 250—36)

This invention relates to piezoelectric crystal apparatus in general. More particularly this invention relates to piezoelectric crystal apparatus for controlling the frequency of an oscillation generator in which the control frequency may be varied.

An object of this invention is to provide a piezoelectric crystal apparatus for controlling the frequency of oscillation generating apparatus in which the controlled frequency may be varied over relatively wide ranges.

Another object of this invention is to provide a piezoelectric crystal apparatus for controlling the frequency of oscillation of a pair of oscillation generators which are connected together to produce a beat frequency which may be varied.

A further object of this invention is to provide a pair of variable piezoelectric crystal holders which are arranged to vary the frequencies of their respective crystals in the opposite orders.

Still another object of this invention is to provide a pair of piezoelectric crystal devices in which the frequency of one of the devices may be increased while the frequency of the other is decreased.

Other and further objects of this invention will be apparent to those skilled in the art to which it relates from the following specification:

This invention is an improvement over the piezoelectric crystal apparatus disclosed in my prior patent No. 2,079,540 and the piezoelectric crystal apparatus disclosed in my application Serial No. 316,269 filed January 29, 1940.

In the present invention use is made of two variable frequency piezoelectric crystal holders of the type disclosed in my prior patent and these are varied together by means of a suitable coupling arrangement so that the variable air-gap in one of the holders is increased while the variable air-gap in the other is decreased. The varying frequencies produced by varying the air-gaps of the crystal holders are heterodyned in suitable oscillator circuits and a variable controlled beat frequency is obtained. This beat frequency may be impressed upon a suitable harmonic amplifier.

A more detailed description of this device and the operation thereof is set forth in the following specification and the drawings, in which, briefly Fig. 1 is a horizontal sectional view of the piezoelectric crystal holder apparatus; Fig. 2 is a view in side elevation of the piezoelectric crystal holder apparatus; Fig. 3 is a view of a modified form electrode control for the piezoelectric crystal apparatus; Fig. 4 is a schematic

diagram of a beat frequency oscillator and Fig. 5 is another schematic diagram of a beat frequency oscillator.

Referring to the drawings in detail reference numerals 10 and 11 designate variable air-gap piezoelectric crystal holders which may be of the type disclosed in my prior Patent No. 2,079,540. Each of these holders 10 and 11 consists of a housing of insulation material such as "Bakelite," "Isolantite," "Alsimag" and the like. Variable electrodes 12 and 14 controlled by the threaded members 20 and 21, respectively, actuated by the manually controlled dial 22, are provided to each of the faces of the piezoelectric crystal elements 14 and 15 housed by the respective holders. These adjustable electrodes 12 and 13 are spring urged by means of springs 16 and 17 respectively so that they normally tend to assume the maximum air-gap positions. Fixed electrodes 18 and 19 are provided to the respective holders and these are in contact with the pin electrodes 24 and 25 respectively. The metallic tops 26 and 27 carrying the metallic threaded members 20 and 21 respectively form the connections to the two electrodes 12 and 13 respectively. Suitable machine screws 28 and 29 are used for fastening the two plates 26 and 27 to the respective crystal housings and in each case one of these machine screws engage the metallic embedded connecting elements 30 and 31 respectively which are connected to the connecting pins 32 and 33 respectively. These connecting pins are engaged by suitable connecting sockets 34 and 35, for example.

The crystal holders 10 and 11 are mounted by means of a suitable bracket 36 to the cabinet panel 37. The manually controlled dial 22 is made of sufficient diameter so that it projects through slots formed in the bracket 36 and the cabinet panel 37 and may be engaged by the thumb of the operator so that the threaded members 20 and 21 of the crystal holders may be conveniently rotated and the adjustable electrodes of the holders thereby adjusted. As one of the threaded members 20—21 is screwed into the corresponding plate 26—27 the other is screwed out. Set screw bushings 38 and 39 supported on springs or spiders 40 and 41, respectively, on opposite sides of the dial 22, are attached by set screws to the ends of the threaded members 20 and 21 respectively. Thus as the dial 22 is rotated one of these threaded members 20—21 is rotated into its associated crystal housing while the other is rotated out. Consequently the air-gap in one of the crystal holders is increased while that in the

other crystal holder is decreased. As a result the frequency of one of the crystals is increased while the frequency of the other crystal is decreased. Inasmuch as the sidewise movement of the dial is rather small this can be taken care of by making the panel slots slightly wider than the dial thickness.

In Fig. 3 I have illustrated a modified form control for the electrodes of the crystal holders. In this case the threaded members 20 and 21 are joined together and collars 23—23 are provided on each side of the dial 22 to limit the sliding movement of the dial with respect to the members 20—21 as these are rotated. In the case of the arrangement shown in Fig. 1 a stop pin 20a is attached to the top plate 26 and the stop pin 20b is attached to the bushing 33. This arrangement limits the rotation of the dial 22 and the members 20—21 to one revolution. This is not the case with the arrangement shown in Fig. 3. The dial 22 is keyed to the members 20 and 21 for rotation thereof so as to control the frequencies of the crystal elements and the corresponding beat frequency resulting from the heterodyning of the frequencies corresponding to the two crystal frequencies. The circumference of the dial 22 may be calibrated in the crystal frequencies and/or the resulting beat frequency or some harmonic thereof.

The crystal elements 14 and 15 are preferably of slightly different frequencies, for example, in practice for amateur operation it may be desirable to produce a beat frequency of nine hundred kilocycles and this may be accomplished by employing a crystal 14 of thirty-nine hundred kilocycles and a crystal 15 of forty-eight hundred kilocycles. These two crystals are provided with separate connections to grid electrodes of suitable beat frequency oscillator tube or tubes which may employ circuits such as shown in Figs. 3 and 4. In Fig. 3 a dual triode type tube such as the 6N7, is employed and the crystal 14 is connected to the grid 42 of one of the triode sections of this tube while the crystal 15 is connected to the grid 43 of the other triode section of this tube. Suitable grid leaks 44 and 45 are connected to these grid electrodes and grounded to the cabinet at 46. The anodes 48 and 49 of the dual triode are connected to the oscillatory circuits 50 and 51 tuned respectively to thirty-nine hundred and forty-eight hundred kilocycles which are the frequencies corresponding to the piezoelectric crystals 14 and 15 respectively. The other terminals of these oscillatory circuits 50 and 51 are connected together to the positive terminal of the anode current supply source and to the bypass condenser 52 the other terminal of which is grounded to the cabinet at 46. A third oscillatory circuit 53 which is tuned to or approximately to the beat frequency of nine hundred kilocycles is connected to the cathodes 54 of the dual triode and the other terminal of this third oscillatory circuit is grounded to the cabinet at 46. Thus the cathodes 54 of the dual triode are at high radio frequency potential with respect to the cabinet or ground and a connection 55 is provided between the high potential side of this third oscillatory circuit 53 and the coupling condenser 56 which is connected to the harmonic amplifier.

The two crystals 14 and 15 employed in the oscillation generator shown in Fig. 3 are controlled together by means of the manually operated control mechanism actuated by the dial 22 shown in Figs. 1 and 2, so that the adjustable electrode of

one of these piezoelectric crystals is moved away from the corresponding crystal while the adjustable electrode of the other piezo electric crystal is moved toward this crystal. In this way the frequency of the oscillations produced in the section of the triode connected, for example, to the piezoelectric crystal 14 is increased, while the frequency of the oscillations generated by the triode section connected to the piezo electric crystal 15 is decreased. Consequently the beat frequency produced in the oscillatory circuit 53 by combining the oscillations derived from the two triode sections, is varied over a range of several kilocycles less than nine hundred kilocycles to several kilocycles above nine hundred kilocycles. More specifically, when the crystal 14 is ground to a frequency of thirty-nine hundred kilocycles and the crystal 15 is ground to a frequency of forty-eight hundred kilocycles the beat frequency may be varied from nine hundred kilocycles minus 12 kilocycles to nine hundred kilocycles plus 15 kilocycles or 888 kc. to 915 kc. because the type of piezoelectric crystals employed permits the frequency of a thirty-nine hundred kilocycle crystal to be varied twelve kilocycles and that of a forty-eight hundred kilocycle crystal to be varied fifteen kilocycles.

By feeding the output of the dual triode beat frequency oscillator shown in Fig. 3 to a harmonic amplifier, the frequency of the nine hundred kilocycle beat frequency oscillations may be stepped up several times and each time the frequency is stepped up the range of frequency variation is also stepped up. Thus if the harmonic amplifier produces a frequency of thirty-six hundred kilocycles from the nine hundred kilocycle beat frequency as a result of stepping up this latter frequency four times, the twenty-seven kilocycle variation would also be extended so that it would result in a one-hundred and eight kilocycle variation. Thus by varying the air-gaps of the crystals 14 and 15 the output frequency of the harmonic amplifier would vary continuously over a range of one-hundred and eight kilocycles.

In Fig. 4 I have illustrated a beat frequency oscillator employing a triode tube 60 and a pentode tube 70 in which the piezoelectric crystal 14 is connected between the grid and plate of the tube 60 and the piezoelectric crystal 15 is connected to the control grid and cathode circuit of the tube 70. The operation of this crystal controlled beat frequency oscillation generator is similar to the operation of the circuit disclosed in my application Serial No. 316,269 referred to in preceding parts of this specification.

A high resistance 61 and a condenser 62 are connected between the grid and cathode of the tube 60. The anode current is fed to the anode of this tube through the radio frequency choke coil 63 and the resistance 92. A suitable bypass condenser is connected between the cathode of this tube and the low radio frequency potential side of the choke 63. The radio frequency output of the tube 60 is fed through the coupling condenser 65 to the mixer grid electrode of the tube 70 which is of a type similar to the 6L7. A high resistance 65 is connected between this mixer grid and the metallic cabinet of the apparatus.

The other piezoelectric crystal 15 is connected to the control grid and the cathode circuit of the tube 70 and this crystal oscillator circuit is of a form such as is described and claimed in my application Serial No. 296,676 filed September 26, 1939.

A high resistance 71 is connected across the

crystal 15 so as to provide a suitable return path between the control grid and the cathode. One terminal of this resistance is grounded to the cabinet as is also one terminal of the radio frequency choke 72 and the re-generation condenser 73. The other terminals of this choke and condenser are connected to the cathode of the tube 70. The screen electrode of the tube 70 is connected to the terminal of the source of anode current supply through the resistance 75 and to the cabinet through the condenser 74. In this way the radio frequency potential of the screen grid electrode is reduced substantially to zero through the condenser 74. The anode current supply source is connected to the anode of the tube 70 through the oscillatory circuit 76 and to the anode of the amplifier tube 80 through the oscillatory circuit 88. These oscillatory circuits consist of inductances 77 and 89 respectively and condensers 78—79 and 90—91 respectively. One condenser in each circuit is variable and these may be mechanically coupled together.

The oscillatory circuit 76 is tuned to the beat frequency of the two piezoelectric crystals 14 and 15 produced by the oscillation generators associated therewith. If the frequencies of the piezoelectric crystals 14 and 15 are the same as those given in connection with Fig. 3 by way of example, so that a nine hundred kilocycle beat frequency is produced the oscillatory circuit 76 is tuned substantially to nine hundred kilocycles.

This beat frequency is fed to the amplifier tube 80 the control grid of which is coupled to the oscillatory circuit 76 through the coupling condenser 81. A suitable grid resistor 84 is connected between this grid and the cathode circuit. A suitable grid biasing resistor 82 is connected between the cathode of the tube 80 and the metallic cabinet to which the negative terminal of the anode current supply is also connected. The suppressor grid of the tube 80 is connected to the cathode and the screen grid is connected to the positive terminal of the anode current supply through the resistance 85. Suitable bypass condensers 86 and 87 are connected to the resistor 85 to bypass the radio frequency to ground.

The oscillatory circuit 88 may be tuned to the same beat frequency as the oscillatory circuit 76 or if desired it may be tuned to some multiple or approximate multiple of this beat frequency so that the tube 80 functions as a harmonic amplifier. Multiplying the frequency of the beat frequency oscillations obtained from the circuit 76 will of course also multiply the frequency variations produced in this beat frequency by varying the air-gaps of the piezoelectric crystals 14 and 15.

The foregoing specification is a description of an embodiment of this invention and I do not desire to limit this invention to the exact details described except insofar as they are defined by the claims.

What I claim is:

1. An adjustable frequency piezoelectric crystal apparatus, comprising: a plurality of piezoelectric crystals, electrodes for said piezoelectric crystals, one of said electrodes for each of said piezoelectric crystals being adjustable with respect to the corresponding surface of the corresponding piezoelectric crystal, means for adjusting the adjustable electrode of one of said piezoelectric crystals toward said last mentioned crystal and for simultaneously adjusting the adjustable electrode of another of said piezoelectric crystals away from said last mentioned crystal

for varying the frequencies of said crystals in the opposite order, and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

2. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals, electrodes for said piezoelectric crystals, one of said electrodes for each of said piezoelectric crystals being adjustable with respect to the corresponding surface of the corresponding piezoelectric crystal, means for moving the adjustable electrode of one of said piezoelectric crystals toward said last mentioned crystal, means for moving the adjustable electrode of the other of said piezoelectric crystals away from said last mentioned crystal for varying the frequencies of said crystals in the opposite order simultaneously, a manually controlled member coupled to each of said means for controlling the frequencies of said piezoelectric crystals, and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

3. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals, electrodes for said piezoelectric crystals, one of said electrodes for each of said piezoelectric crystals being adjustable with respect to the corresponding surface of the corresponding piezoelectric crystal, means for adjusting the adjustable electrode of one of said piezoelectric crystals toward said last mentioned crystal and means for adjusting the adjustable electrode of the other of said piezoelectric crystals away from said last mentioned crystal for varying the frequencies of said crystals in the opposite order, a manually controlled rotatable member coupled to both of said means for adjusting said means simultaneously, and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

4. An adjustable frequency piezoelectric crystal apparatus, comprising: a plurality of piezoelectric crystals, electrodes for said piezoelectric crystals, one of said electrodes for each of said piezoelectric crystals being adjustable with respect to the corresponding surface of the corresponding piezoelectric crystal, preformed mechanical means for adjusting the adjustable electrode of one of said piezoelectric crystals toward said last mentioned crystal and for simultaneously adjusting the adjustable electrode of another of said piezoelectric crystals away from said last mentioned crystal for varying the frequencies of said crystals in the opposite order, and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

5. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals upward and for simultaneously varying the frequency of oscillation of the other of said piezoelectric crystals downward and means for producing a continuously variable beat frequency from said piezoelectric crystal oscillations.

6. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals upward and for simultaneously varying the frequency of oscillation of the

other of said piezoelectric crystals downward, a pair of oscillation generators connected to said piezoelectric crystals, one to each crystal, for producing electric oscillations corresponding in frequencies to the frequencies of said piezoelectric crystals, and means for producing a continuously variable beat frequency from said electric oscillations.

7. Piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals, a pair of variable air-gap piezoelectric crystal holders each having a screw threaded member for adjusting the air-gap between an electrode and the corresponding crystal surface, a manually adjustable dial member coupled to said screw threaded member of each of said crystal holders for adjusting said air-gaps in the opposite orders for increasing the frequency of one of said crystals and simultaneously decreasing the frequency of the other of said crystals and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

8. Piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals, a pair of variable air-gap piezoelectric crystal holders each having a screw threaded member for adjusting the air-gap between an electrode and the corresponding crystal surface, the screw threaded members of said holders being substantially axially aligned, a manually adjustable dial member positioned between said screw threaded members and coupled thereto for adjusting said air-gaps in the opposite orders for increasing the frequency of one of said crystals and simultaneously decreasing the frequency of the other of said crystals and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

9. Piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals, a pair of variable air-gap piezoelectric crystal holders each having a screw threaded member for adjusting the air-gap between an electrode and the corresponding crystal surface, a bracket for supporting said crystal holders and for holding said screw threaded members thereof substantially in axial alignment, a manually adjustable dial member supported by said screw threaded members for adjusting said air-gaps in the opposite orders for increasing the frequency of one of said crystals and simultaneously decreasing the frequency of the other of said crystals and means for producing a continuously variable beat frequency from the frequencies of said piezoelectric crystals.

10. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals upward and for simultaneously varying the frequency of oscillation of the other of said piezoelectric crystals downward, electron discharge device means having a pair of grid electrodes and cathode means, connections for connecting one terminal of one of said piezoelectric crystals to one of said grid electrodes and one terminal of the other of said piezoelectric crystals to the other of said grid electrodes, a pair of anodes for said electron discharge device means, a pair of tuned circuits each having a terminal thereof connected to one of said anodes, said tuned circuits being tuned substantially to frequencies of said piezoelectric crystals respectively, connections for connecting the other terminals of said piezoelectric crystals together, means for connecting said last mentioned terminals to said cathode means, connections for connecting the other terminals of said pair of tuned circuits together and a source of current supply connected between said last mentioned terminals and the connected terminals of said piezoelectric crystals.

11. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals for producing variable beat frequency oscillations with the other piezoelectric crystal, electron discharge device means having a pair of grid electrodes and cathode means, connections for connecting one terminal of one of said piezoelectric crystals to one of said grid electrodes and one terminal of the other of said piezoelectric crystals to the other of said grid electrodes, a pair of anodes for said electron discharge device means, a pair of tuned circuits each having a terminal thereof connected to one of said anodes, said tuned circuits being tuned substantially to frequencies of said piezoelectric crystals respectively, an auxiliary tuned circuit tuned substantially to the beat frequency of said piezoelectric crystal frequencies, connections for connecting one terminal of said auxiliary tuned circuit to the other terminals of said piezoelectric crystals and the other terminal of said auxiliary tuned circuit to said cathode means, the other terminals of said pair of tuned circuits being connected together, and a source of current supply connected between said last mentioned terminals and the connected terminals of said piezoelectric crystals.

12. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals upward and for simultaneously varying the frequency of oscillation of the other of said piezoelectric crystals downward, electron discharge device means having a pair of grid electrodes and cathode means, connections for connecting one terminal of one of said piezoelectric crystals to one of said grid electrodes and one terminal of the other of said piezoelectric crystals to the other of said grid electrodes, a pair of anodes for said electron discharge device means, a pair of tuned circuits each having a terminal thereof connected to one of said anodes, said tuned circuits being tuned substantially to frequencies of said piezoelectric crystals respectively, connections for connecting the other terminals of said piezoelectric crystals together, means for connecting said last mentioned terminals to said cathode means, connections for connecting the other terminals of said pair of tuned circuits together and a source of current supply connected between said last mentioned terminals and the connected terminals of said piezoelectric crystals.

13. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals, means for simultaneously varying the frequency of oscillation of the other of said piezoelectric crystals, electron discharge device means having a pair of grid electrodes and cathode means, connections for connecting one terminal of one of said piezoelectric crystals to one of said grid electrodes and one terminal of the other of said piezoelectric crystals to the other of said grid electrodes, a pair of anodes for said electron discharge device means, a pair of tuned circuits each having a terminal thereof connected to one of said anodes, said tuned circuits being tuned substantially to frequencies of said piezoelectric crystals respectively, connections for connecting the other terminals of said piezoelectric crystals together, means for connecting said last mentioned terminals to said cathode means, connections for connecting the other terminals of said pair of tuned circuits together and a source of current supply connected between said last mentioned terminals and the connected terminals of said piezoelectric crystals.

14. An adjustable frequency piezoelectric crystal apparatus, comprising: a pair of piezoelectric crystals of different frequencies for producing beat frequency oscillations, means for varying the frequency of oscillation of one of said piezoelectric crystals, means for simultaneously varying the frequency of oscillation of the other of said piezoelectric crystals, electron discharge device means having a pair of grid electrodes and cathode means, connections for connecting one terminal of one of said piezoelectric crystals to one of said grid electrodes and one terminal of the other of said piezoelectric crystals to the other of said grid electrodes, a pair of anodes for said electron discharge device means, a pair of tuned circuits each having a terminal thereof connected to one of said anodes, said tuned circuits being tuned substantially to frequencies of said piezoelectric crystals respectively, connections for connecting the other terminals of said piezoelectric crystals together, means for connecting said last mentioned terminals to said cathode means, connections for connecting the other terminals of said pair of tuned circuits together and a source of current supply connected between said last mentioned terminals and the connected terminals of said piezoelectric crystals.

the frequency of the other of said piezoelectric crystals in the opposite order for producing variable beat frequency oscillations with said first mentioned piezoelectric crystal, electron discharge device means having a pair of grid electrodes and cathode means, connections for connecting one terminal of one of said piezoelectric crystals to one of said grid electrodes and one terminal of the other of said piezoelectric crystals to the other of said grid electrodes, a pair of anodes for said electron discharge device means, electrically periodic means connected between said anodes being electrically periodic at frequencies corresponding substantially to those of said piezoelectric crystals, connections for connecting the other terminals of said piezoelectric crystals together, means for connecting said last mentioned terminals to said cathode means and a source of current supply connected between said electrically periodic means and the connected terminals of said piezoelectric crystals.

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