Feb. 24, 1942. W. R. KOCH 2,274,486

PIEZOELECTRIC RESONATOR CIRCUIT

Filed May 18, 1940

Fig. 1.

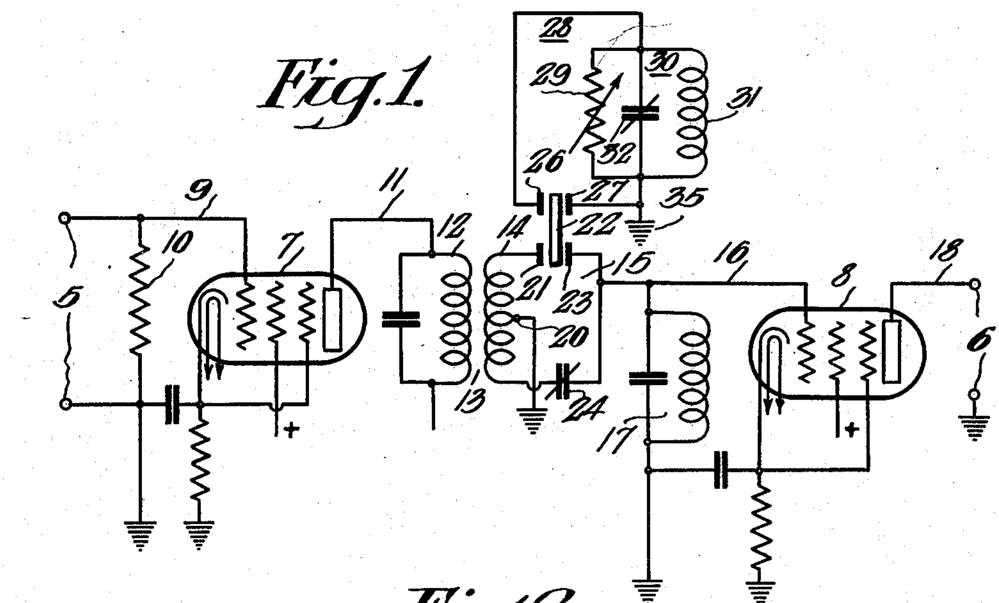
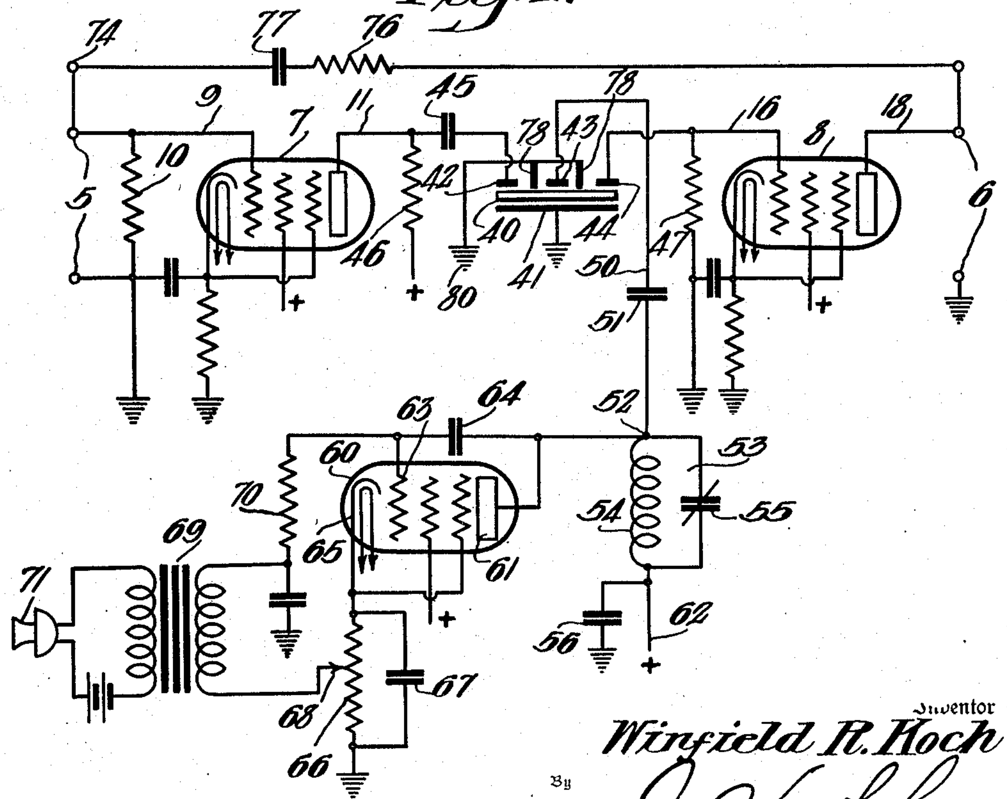


Fig. 2.



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PIEZOELECTRIC RESONATOR CIRCUIT

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10 Claims. (Cl. 179—171.5)

This invention relates to piezo-electric resonator circuits adapted generally for filtering, oscillation generation, and frequency modulation.

It is an object of this invention to provide an improved circuit and means for changing the resonant frequency and the damping of piezo-electric resonators in selective signal transmission, oscillation generating and frequency modulation circuits, without changing the constants or arrangements of such circuits, as has been necessary heretofore, with known circuits of the character referred to.

It is also an object of this invention to provide an improved piezo-electric resonator system and control circuit therefor which is readily adapted for the generation and control of frequency modulated signals.

In accordance with the invention, the coating on the crystal surface or the electrode area of a crystal element in a signal conveying circuit is divided, and a segregated area or certain segregated areas are connected to a suitable reactance or resistance network included in a separate control circuit by which the frequency and damping of the signal conveying circuit through the crystal or piezo-electric resonator is controlled, the control circuit being coupled with the signal channel only through the crystal element of the resonator circuit.

The invention will, however, be better understood from the following description when considered in connection with the accompanying drawing, and its scope is pointed out in the appended claims.

In the drawing,

Figure 1 is a schematic circuit diagram of a piezo-electric resonator circuit embodying the invention, and

Figure 2 is a further schematic circuit diagram of a modification of the circuit of Fig. 1, also embodying the invention and adapted for frequency modulation.

Referring to Fig. 1, a portion of a high frequency signal transmission circuit is shown, comprising input terminals 5 and output terminals 6 between which are connected two amplifier stages in cascade, comprising amplifier tubes 7 and 8.

The first stage amplifier 7 comprises an input grid circuit 9 having an input impedance 10 connected across the terminals 5, and an output anode circuit 11 which includes the tuned primary winding 12 of a high frequency interstage coupling transformer 13.

The secondary 14 of the transformer 13 is connected through a balanced crystal circuit 15 with the grid input circuit 16 of the second stage 8 which includes a tuned circuit 17, and the output anode circuit 18 is connected with the terminals 6.

The tuned circuits shown may be tuned to the crystal frequency, in which case the circuit operates to convey signals at that frequency, amplified in the stages 7 and 8, from the input terminals 5 to the output terminals 6.

The crystal circuit is provided with a grounded center tap 20 on the secondary 14 and a circuit from one terminal of the secondary to an input electrode 21 on the crystal element 22. An output electrode 23 is connected to the high side of the input circuit 16 and through a neutralizing capacitor 24 to the opposite terminal of the secondary. Signals are conveyed through the circuit between the ground connection 20 and the high side of the circuit, thence through the crystal to the imput circuit 16. The crystal capacity is neutralized by proper adjustment of the capacitor 24. The crystal may be of any suitable material, such as Rochelle salt or quartz.

A suitable area of the crystal, segregated and apart from the areas occupied by the main electrodes 21 and 23, is provided for signal control purposes, in accordance with the invention, with auxiliary control electrodes. In the present example, two such separate electrodal areas are indicated at 26 and 27 at the opposite end of the crystal from the electrodes 21 and 23. The control or auxiliary electrodes are connected with a control circuit 28 which includes a predetermined resistance or reactance 29, together with a tuned circuit 30 in shunt therewith and effective to tune out the inherent shunting capacity of the electrodes 26 and 27 across the impedance or reactance device 29.

The reactance device is preferably a resistor, as shown, having no appreciable frequency characteristic and the circuit 30 preferably includes a tuning inductance 31 and adjustable shunt capacitor 32, this circuit being preferably tunable through a frequency range determined by the desired range of variation of the frequency of the resonator circuit.

With the circuit arrangement shown, the frequency and damping of the resonator circuit 15 may be changed without change in the associated input and output circuits, as commonly required, and without changing the dimensions of the resonator circuit electrodes.

By dividing the coating or electrode area on the crystal surface, as shown, and connecting a suitable reactance or resistance to the segregated area, it has been found that changes in frequency or damping may readily be obtained as a result of varying the reactance or resistance in the control circuit, or the resonant frequency of a tuned circuit which includes the segregated crystal area or areas.

In other words, the resistive component of impedance in circuit with the third or control electrode may be adjusted to a value of the order of the resistive component of the crystal impedance for maximum damping and attenuation of signals through the crystal.

For increasing the damping, a resistance device such as that shown at 29 may be made to match that of the segregated area between the electrodes 26 and 27 so that the resistance device will absorb power sufficient to reduce effectively the selectivity afforded by the areas 21 and 23 connected with the signal conveying circuit.

Furthermore, by providing segregated electrode or coating areas on the crystal, the control circuit may be operated at low potential to ground. Thus, as shown, one of the electrodes 27 may be connected to ground along with the low potential side of the impedance 29 and the tuned circuit 30, as indicated at 35. With this arrangement, the electrodes 26 and 27 and the control circuit have no appreciable undesired effects upon the signal selecting portion of the system, such as the crystal resonator circuit 15.

The impedance of the element 29 is preferably higher than the effective impedance of the parallel resonant circuit 30 and may be of the order of several thousand ohms, or may be increased above that value with regeneration applied thereto.

With the circuit 30 tuned to resonance with the crystal, variation of the impedance 29 causes the impedance of the crystal in the signal conveying resonator circuit 15 to vary, thereby causing the signal transmission or gain through the circuit to vary, together with the selectivity of the circuit 15.

It has been found that by varying the tuning of the circuit 30 from resonance, that is, by detuning the circuit 30, the frequency response of the crystal may be varied in a relatively wide range on either side of the resonance frequency. Therefore, this arrangement provides means for shifting the frequency of the piezo-electric resonator circuit without direct connection with the circuit and wholly through the crystal coupling.

Variation of the impedance 29, with the control circuit 30 detuned, causes a change in the phase and amplitude of signals transmitted through the circuit 15, and therefore variation of the impedance under such conditions provides ready means for phase and amplitude modulation of signals transmitted through the piezo-electric resonator circuit.

Referring now to Fig. 2 in which the same reference numerals are used to designate like circuits and circuit elements, the amplifier stages 7 and 8 which are connected between the input terminals 5 and the output terminals 6 as in the circuit of Fig. 1. The interstage coupling system is a modification of the piezo-electric resonator circuit of Fig. 1 in which the crystal is indicated at 40 having on one face thereof a grounded electrode or coating 41 and on other or opposite faces a plurality of electrode or coated areas indicated at 42, 43 and 44, the first and the last being the crystal input and output electrodes, respectively. The input electrode 42 is coupled through a capacitor 45 with the output circuit 11 of the first stage 7 across a suitable anode impedance, preferably an anode resistor 46 having no appreciable frequency characteristic. The output electrode 44 is connected with the input circuit 16 of the output stage 8 across a grid resistor 47.

With this arrangement, signals are conveyed through the crystal coupling between the electrodes 42 and 44, from the output circuit 11 to the input circuit 16. The control circuit in the present example is connected between the segregated electrodal area provided at 43, preferably intermediate between the electrodes 42 and 44, and ground or the opposite common electrode 41.

The control circuit includes a lead 50 connected between the electrode 43 and a coupling capacitor 51 which, in turn, is connected with the high potential terminal 52 of a tuned resonant circuit 53 comprising an inductance 54 and a shunt capacitor 55. The low potential side of the circuit 53 is connected to ground through a bypass capacitor 56 and thence to the common electrode 44 on the crystal or piezo-electric resonator circuit. Thus, the circuit 53 is connected substantially in shunt across the electrodes 43 and 41, since the capacitors 51 and 56 are preferably of relative low impedance or reactance at the resonant frequency or circuit 53.

As in the circuit of Fig. 1, variation of the tuning of the control circuit 53 from resonance, that is, from the crystal frequency, is effective to cause a shift in the resonant frequency of the crystal 40 and this may be controlled by any suitable means. For example, the variation in frequency may be made in accordance with an audio modulation frequency by connecting a variable reactance tube 60 with the circuit 53, as shown, the plate 61 of the tube being connected through the inductance 54 to a positive supply source indicated by the lead 62 and being coupled to the control grid 63 through a coupling or feedback capacitor 64.

In the present example, the tube 60 is of the screen grid pentode type having a cathode 65 connected to ground through a suitable bias resistor 66 provided with a bypass capacitor 67. A variable bias is derived from the resistor 66 through a tap connection 68 connected back to the control grid 63 through an input circuit comprising a transformer secondary 69 and a grid resistor 70. By varying the bias potential provided by the tap 68, the loading of the tube 60 may be controlled and adjusted to such a value that the circuit 53 is in resonance with the crystal frequency, or the adjustment may provide for shifting the resonant frequency of the crystal as desired.

The resonant frequency of the circuit 53 may then be further shifted to vary the resonant frequency of the crystal circuit by applying modulation signals to the grid 63 through the transformer 69 from any suitable source such as a microphone 71.

In order to produce frequency modulation, oscillations representing the mean frequency or carrier are transmitted through the crystal circuit, for example, by connecting the high potential output terminal 6 through a feedback circuit 73 to a feedback input terminal 74 which is connected to the high potential side of the input circuit 5, thereby causing the system to oscillate at the crystal frequency. The strength of oscillations is determined by a series controlling resistor 76 in the feedback circuit, and the output anode circuit 18 is decoupled for direct currents, from the input circuit, by a capacitor 77 also in the lead 73.

It will be noted that the input electrode 43 and the output electrode 44 are shielded from the control electrode 43 on the crystal by shield plates 78 interposed between the electrodes and connected to ground 80. This effectively prevents any interaction between electrodes except through the crystal.

From the foregoing description, it will be seen that a piezo-electric resonator in a signal-conveying circuit may be controlled by an auxiliary circuit wholly disconnected from the signal-conveying and resonator circuits and being coupled to the resonator circuit only through the piezo-electric device or crystal.

Furthermore, the signal gain through the resonator circuit may be varied or the frequency of the piezo-electric resonator may be varied on either side of the resonance by means of suitable impedance or reactance devices in the auxiliary control circuit, and auxiliary electrode means associated with the piezo-electric device in the resonator circuit associated with areas of the said device not associated with the main electrodes.

In any system embodying the invention, it will be seen that the piezo-electric device in the resonator circuit is provided with signal input and output electrodes and an auxiliary electrode preferably shielded from the input and output electrodes and connected with the isolated control circuit containing the tuning or impedance varying device or circuit network.

Amplitude and phase modulation results from detuning the control circuit from the crystal frequency and varying the impedance of the circuit, whereas amplitude control alone is provided when the control circuit is tuned to the crystal frequency.

Frequency modulation of oscillations transmitted through the crystal or piezo-electric device may be provided in the same manner through the use of the auxiliary electrode connection with the crystal and the auxiliary control circuit containing a variable reactance device responsive to the modulation signals. It is apparent that the reactance device 60 may be replaced by any other suitable or equivalent means capable of performing the same function.

I claim as my invention:

1. In a high frequency signal conveying system, a piezo-electric crystal-controlled oscillation-generating circuit, oscillation control means including a piezo-electric crystal and a pair of signal-conveying electrodes therefor, circuit means connected with said electrodes for conveying signals through said crystal as a circuit coupling element, a third electrode for said crystal in spaced relation to said first-named electrodes, an impedance in circuit with said third electrode, and means for adjusting the resistive component of said impedance to a value of the order of the value of the resistive component of the crystal impedance.

2. In a high frequency signal conveying system, a piezo-electric crystal-controlled oscillation-generating circuit, oscillation control means including a piezo-electric crystal and a pair of signal-conveying electrodes therefor, circuit means connected with said electrodes for conveying signals through said crystal as a circuit coupling element, a third electrode for said crystal in spaced relation to said first-named electrodes, and a variable reactance circuit connected with said third electrode for varying the resonant frequency of the crystal.

3. In a high frequency signal conveying system, a piezo-electric crystal-controlled oscillation-generating circuit, oscillation control means including a piezo-electric crystal and a pair of signal-conveying electrodes therefor, circuit means connected with said electrodes for conveying signals through said crystal as a circuit coupling element, a third electrode for said crystal in spaced relation to said first named electrodes, a variable reactance circuit connected with said third electrode for varying the resonant frequency of the crystal, and means providing a shield between said third electrode and said first named electrodes.

4. In a high frequency signal-conveying system, a piezo-electric resonator circuit comprising a piezo-electric crystal for determining the frequency of signals transmitted therethrough, means providing a signal input and a signal output electrode for said crystal, signal conveying circuits coupled to said input and output electrodes responsive to signals at a frequency of the order of the crystal frequency, means providing an auxiliary electrode associated with said crystal, and means providing a reactance in circuit with said auxiliary electrode for determining the frequency of oscillation of said crystal between predetermined limits.

5. In a high frequency signal-conveying system, a piezo-electric resonator circuit comprising a piezo-electric crystal for determining the frequency of signals transmitted therethrough, means providing a signal input and a signal output electrode for said crystal, signal conveying circuits coupled to said input and output electrodes responsive to signals at a frequency of the order of the crystal frequency, means providing an auxiliary electrode associated with said crystal, means providing reactance in circuit with said auxiliary electrode for determining the frequency of oscillation of said crystal between predetermined limits, and means for varying the impedance of said crystal between said input and output electrodes comprising a variable resistance element connected in circuit with said auxiliary electrode.

6. In a piezo-electric crystal-controlled signal-conveying system, the combination of a piezo-electric crystal device for controlling the frequency of electric oscillations conveyed therethrough and including a pair of electrodes associated with said crystal device, circuit means connected with said electrodes for conveying oscillations through said crystal device as a circuit coupling element, an auxiliary control electrode associated with said crystal device, an auxiliary control circuit connected with said last-named electrode, variable impedance means in said circuit, and means in shunt therewith for neutralizing the capacity of said electrode.

7. In a piezo-electric crystal-controlled signal-conveying system having a piezo-electric crystal provided with signal input and output electrodes, signal-conveying circuits connected with said electrodes, circuit means connected with said electrodes for conveying signals through said crystal as a circuit coupling element, an auxiliary electrode associated with said crystal in spaced relation to said first-named electrodes, a tuned circuit connected with said last-named electrode, and means for varying the reactance of said cir-

cuit thereby to vary the signal transmission characteristic of said crystal.

8. A piezo-electric resonator circuit comprising, in combination, a piezo-electric crystal device having an input electrode and an output electrode, means connected with said electrodes for conveying electrical oscillations through said crystal at a frequency of the order of the crystal frequency, an auxiliary electrode for said crystal, a variable reactance circuit connected with said electrode, and means responsive to sound frequencies for varying the reactance of said last-named circuit.

9. In a high frequency signal-conveying system, the combination with a signal amplifier, of an interstage coupling network comprising, in combination, a piezo-electric crystal having an input electrode and an output electrode, circuit means connected with said electrodes for conveying signals through said crystal as a circuit coupling element, a pair of additional electrodes associated with a predetermined area of said crystal in spaced relation to said first-named electrodes, a control circuit connected between said last-named electrodes, and means providing a variable impedance in said control circuit for varying the transmission characteristic of said first-named circuit means.

10. In a high frequency signal-conveying system, the combination with a signal amplifier, of an interstage coupling network comprising, in combination, a piezo-electric crystal having an input electrode and an output electrode, circuit means connected with said electrodes for conveying signals through said crystal as a circuit coupling element, a pair of additional electrodes associated with a predetermined area of said crystal in spaced relation to said first-named electrodes, a control circuit connected between said last-named electrodes, means providing a variable impedance in said control circuit for varying the transmission characteristic of said first-named circuit, one of said last-named electrodes being grounded, and means providing a grounded screen between at least one of said auxiliary electrodes and said first-named electrodes.

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