

Oct. 17, 1933.

W. A. MARRISON

1,931,028

PIEZO-ELECTRIC RELAY

Filed March 6, 1929

2 Sheets-Sheet 1

FIG. 1.

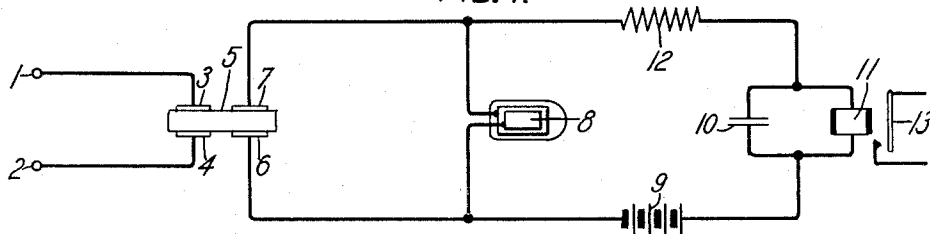


FIG. 2.

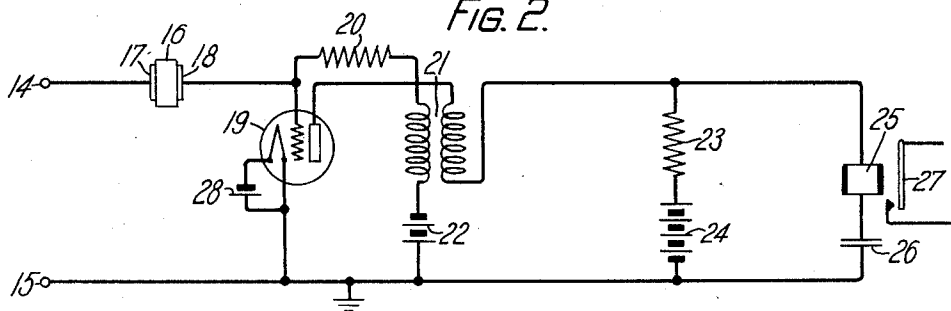


FIG. 3.

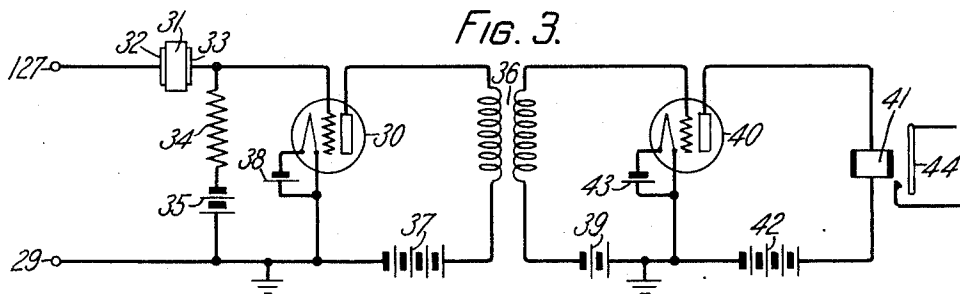
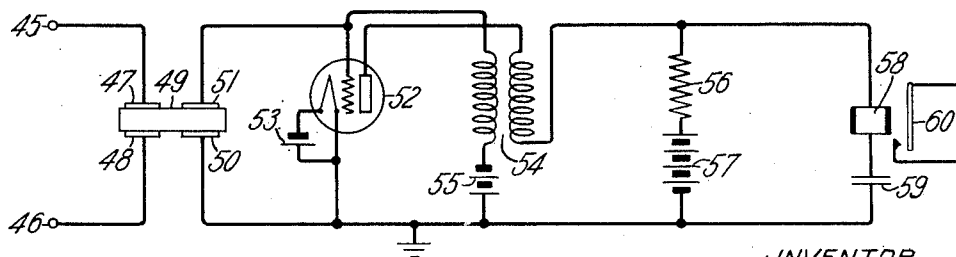


FIG. 4.



INVENTOR
W. A. MARRISON
BY *Guy T. Morris*
ATTORNEY

Oct. 17, 1933.

W. A. MARRISON

1,931,028

PIEZO-ELECTRIC RELAY

Filed March 6, 1929

2 Sheets-Sheet 2

FIG. 5.

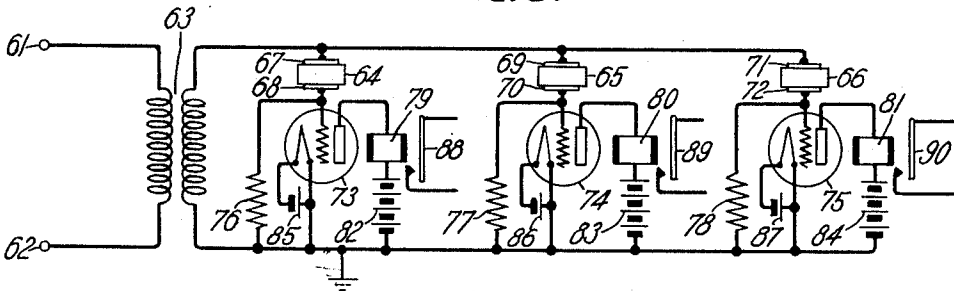


FIG. 6.

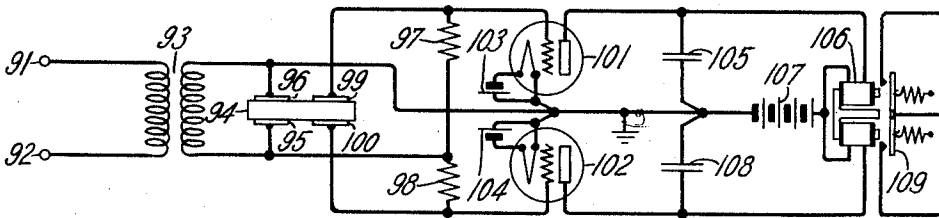
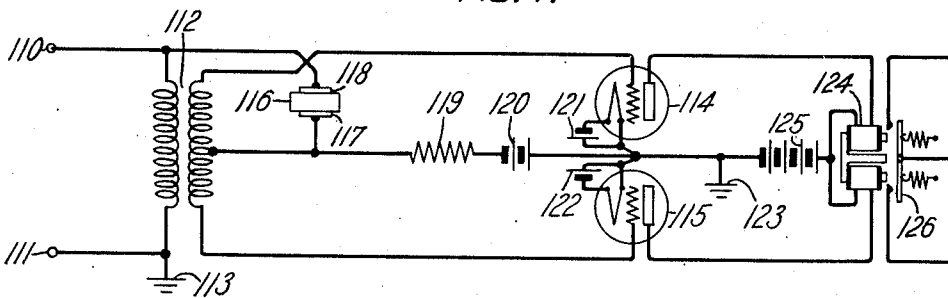


FIG. 7.



INVENTOR
W. A. MARRISON
BY
Guy T. Morris
ATTORNEY

UNITED STATES PATENT OFFICE

1,931,028

PIEZO-ELECTRIC RELAY

Warren A. Marrison, Maplewood, N. J., assignor
to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application March 6, 1929. Serial No. 344,858

10 Claims. (Cl. 250—27)

This invention relates to piezo-electric relays and particularly to apparatus in which a piezo-electric device is used as a filter to select a wave of a desired frequency and that wave either
5 directly or through auxiliary apparatus operates a relay.

An object of this invention is to achieve wave selection on a frequency discrimination basis, more accurately and with more sensitive and
10 positive response than by prior methods or means.

Another object of this invention is to provide means for such wave selection which is not responsive to any other than a desired frequency.

Another object of this invention is to provide means highly sensitive and selective to a wave of a desired frequency, to actuate signal means to denote the presence of a wave of that frequency.

A feature of this invention is the provision of a source of energy in association with a neon tube or other gas-filled electrical discharge device and a piezo-electric resonator, the source of energy being so adjusted that the electromotive
25 force is just below the value that will cause the neon tube to break and the piezo-electric resonator being adapted when excited to cause an increase in the electromotive force sufficient to pass a current through the tube.

Another feature of this invention is the provision of a piezo-electric resonator in association with a three-electrode space discharge device so adjusted that normally no current will flow in the space current path thereof.

Any substance such as a piezo-electric substance, for example, which exhibits a high degree of elasticity and a high density in proportion to its viscosity will, if excited into resonant vibration, vibrate at considerably greater amplitude at its resonance frequency than at other frequencies and will be sharply selective to this frequency.

If a condenser and a two-electrode gas-filled tube, such as a neon tube, for example, are
45 connected in parallel across a source of energy in series with a resistance, the constants of the elements being suitably proportioned, the condenser will be charged to a point such that the breakdown point of the two-element tube will be reached and a current will flow between its electrodes. A circuit adapted to operate in this manner is known as a "relaxation oscillator". If a piezo-electric resonator is now connected in parallel with the condenser and two-element
55 tube, the resonator, on the breakdown of the

tube, will receive a shock which will excite it into vibration at its resonant frequency, and subsequent breakdowns of the tube will occur at the frequency of the resonator or at a sub-harmonic thereof.

This invention contemplates the use of such a system in which the voltage supplied by the source of energy is below the breakdown point of the tube. Coupled to the piezo-electric resonator is a source of signals, and in series with
65 the gas-filled tube are the windings of a relay. When voltage of any other frequency than a resonance frequency of the resonator is impressed on the resonator, the voltage on the tube is still insufficient to break it down, but
70 when the impressed voltage is of a resonance frequency of the resonator, it is excited into vibration at sufficient amplitude to produce a voltage across the gas-filled tube sufficient to break it down, and current will flow through
75 the tube and the windings of the relay.

In other modifications of the invention a three-electrode space discharge device is used, in the output circuit of which normally no current is flowing, and incoming signals of the
80 frequency of a mechanical vibrating element are utilized to cause a current to flow therein.

In the drawings, Fig. 1 is a circuit diagram of apparatus in accordance with this invention in which a neon or other gas-filled tube is
85 used.

The remaining figures of the drawings illustrate modifications of the invention in which one or more three-electrode space discharge devices are used and one or more mechanical
90 vibrating elements.

In the circuit of Fig. 1 an incoming signal across the leads 1, 2 is impressed by means of electrodes 3, 4 upon a mechanical vibrating element 5, which may be of quartz or other piezo-electric material. A sound pair of electrodes
95 6, 7 are mounted adjacent to the mechanical vibrating element and conduct the signal currents derived from element 5 by piezo-electric transformation to a two-electrode gas-filled discharge device 8 which may be a neon tube. Mounted in parallel with said neon tube is a series circuit comprising a battery 9, a branched circuit having a condenser 10 and relay 11 in parallel paths, and a resistance 12. The
100 condenser and resistance may be variable if desired. The relay is adapted on energization to actuate its armature 13.

In the circuit of Fig. 2 input signals across leads 14, 15 are impressed through a mechanical
110

vibrating element 16, having piezo-electric properties and having two electrodes 17, 18, on a three-electrode space discharge device 19. Across the input electrodes of said device are connected in series a resistance 20, the secondary of a transformer 21, and a grid biasing battery 22. Connected in series across the output electrodes of said device are the primary winding of the transformer 21, resistance 23, and space current battery 24. In parallel with said last mentioned resistance and battery, 23 and 24, are the windings of a relay 25, and a condenser 26, in series. Relay 25 is adapted when energized to actuate its armature 27. The filament of the three-electrode space discharge device 19 is heated by means of a battery 28.

In the circuit of Fig. 3 input signals from leads 127 and 29 are impressed on a three-electrode space discharge device 30 through a mechanical vibrating element 31, having piezo-electric properties, and having two electrodes 32, 33. Across the grid-filament electrodes of said device 30 are a resistance 34 and a grid-biasing battery 35 in series. Across the output electrodes of said device 30 are the primary winding of a transformer 36 and a space current battery 37. The filament of said device 30 is heated by a battery 38. The secondary winding of the transformer 36 is connected in series with a grid-biasing battery 39 across the grid-filament electrodes of a second space discharge device 40. In the output circuit of this second space discharge device are the windings of a relay 41 and a space current battery 42 in series. The filament of device 40 is heated by battery 43. The relay 41 is adapted when energized to actuate its armature 44.

In the circuit of Fig. 4 a signal received on leads 45, 46 is impressed by means of electrodes 47, 48 upon a mechanical vibrating element 49 having piezo-electrode properties. Coupled to said vibrating element 49 by means of a second pair of electrodes 50, 51 is a three-electrode space discharge device 52, the filament of which is heated by means of a battery 53. Connected across the grid-filament electrodes of the space discharge device 52 in parallel with electrodes 50, 51 adjacent to the electrical vibrating element 49, is the secondary winding of a transformer 54 and a grid-biasing battery 55 in series. Connected in series across the output electrodes of said device 52 is the primary of the transformer 54, a resistance 56 and a space current battery 57. In parallel with the resistance 56 and space current battery 57 are the windings of a relay 58 and a condenser 59. The relay 58 is adapted when energized to actuate its armature 60.

In the circuit of Fig. 5 input signals on leads 61, 62 are conducted to the primary winding of a transformer 63. The secondary winding of transformer 63 is connected through a plurality of piezo-electric devices 64, 65, 66 having pairs of electrodes 67, 68, 69, 70, 71, 72, respectively, adjacent thereto, to a plurality of three-electrode space discharge devices 73, 74, 75, respectively. Across the input electrodes of these space discharge devices, in parallel with the secondary winding of transformer 63 and its particular piezo-electric device, are grid-biasing resistances 76, 77, 78 respectively. Across the output electrodes of the devices are connected the windings of relays 79, 80, 81, each of these relay windings being in series with a corresponding space current battery 82, 83 or 84 respectively.

The filaments of the devices are heated by batteries 85, 86, 87 respectively. The relays 79, 80, 81 are adapted when energized to actuate their armatures 88, 89, 90 respectively.

In the circuit of Fig. 6 an incoming signal from leads 91, 92 is impressed on the primary winding of a transformer 93. The secondary winding of said transformer 93 is connected across a piezo-electric device 94 by means of a pair of electrodes 95, 96, adjacent thereto. Coupled to said piezo-electric device by means of a second pair of electrodes 99, 100, are three-electrode space discharge devices 101, 102, whose filaments are heated by means of batteries 103, 104 respectively. One side of the secondary of said transformer 93 is connected to the filaments of said space discharge devices 101, 102, and the other side is connected to a mid-point between the grids of said devices and electrically separated from said grids by means of two resistances 97, 98. Across the output electrodes of space discharge device 101 is connected a condenser 105, and in parallel therewith one-half of the windings of a balanced, polarized relay 106 and space current battery 107. Connected across the output electrodes of space discharge device 102 is a condenser 108, and in parallel therewith the other half of the windings of the balanced polarized relay 106, and space current battery 107 which is common to the two space discharge devices. Relay 106 is adapted when energized to actuate its armature 109.

In the circuit of Fig. 7, an incoming signal across leads 110 and 111 is impressed upon the primary winding of transformer 112, one side of which is connected to ground 113. The secondary winding of transformer 112 is connected to the grids of three-electrode space discharge devices 114, 115 and the mid-point of the secondary winding is connected to the filaments of said devices, through a resistance 119, and a grid-biasing battery 120. The mid-point of the secondary is also connected to one electrode 117 of a piezo-electric device 116. The side of the primary of said transformer 112 which is not grounded is connected to the other electrode 118 of the piezo-electric device. The filaments of space discharge devices 114, 115 are heated by means of batteries 121, 122 respectively and are connected to ground 123. The output electrodes of space discharge device 114 are connected through one-half of the windings of a balanced polarized relay 124, and space current battery 125 which is common to the two devices. The output electrodes of space discharge device 115 are connected through the other half of the windings of relay 124 and space discharge battery 125. The windings of relay 124 are arranged to differentially affect armature 126 of relay 124.

In the operation of the device of Fig. 1 the battery 9 impresses a potential on the electrodes 6, 7 of the piezo-electric device 5 through the resistance 12. These electrodes perform the function of a condenser, having the piezo-electric crystal for a dielectric, and in a time depending upon the value of the resistance, a potential equal to that across the output of the battery will build up across these electrodes. This potential will be impressed upon the electrodes of the neon tube, but is insufficient to break down the tube and cause it to become conductive. An incoming signal is impressed upon the piezo-electric device by means of its electrodes 3, 4. This signal will cause an increased

potential to be applied to the electrodes of the neon tube. However, this potential is still insufficient to break down this tube unless the signals are of a particular frequency. When the impressed signals are of a frequency which is a resonant frequency of the piezo-electric resonator 5, the resonator will be excited into resonant vibration at greater amplitude than at any other frequency, and an alternating potential of corresponding amplitude will be impressed across the electrodes of the neon tube. This potential is sufficient to cause the tube to break down and become conductive, and a current will therefore flow through the tube, and through the windings of the relay 11. The neon tube will continue to pass a pulse of current with each cycle of the vibrations of the piezo-electric device or, depending upon the values of the constants of the circuit, at some sub-harmonic thereof. The relay 11 will therefore be energized and will operate its armature 13. Condenser 10 serves to pass the alternating component of the neon tube current. This relay, or the relays shown in any of the figures, may be made self-releasing or self-sustaining.

This apparatus will give a visible indication, through the neon tube, of the operation of the relay.

In the operation of the device of Fig. 2 incoming signals are impressed upon the space discharge tube 19 through the piezo-electric device 16. The grid biasing battery 22 normally applies such a bias to the grid that no current will flow in the space current path of the tube. The positive potential for the plate of the tube is supplied by the battery 24 through the resistance 23. This battery will build up a charge on condenser 26 which will be applied to the plate and will assume the maximum potential of the battery in a time depending upon the constants of the circuit. Energy from the output circuit of the tube is fed back to the input circuit through the transformer 21. When signals of other frequencies than a resonant frequency of the piezo-electric crystal 16 are impressed thereon, no effect will be observed in the output circuit of the tube since no current will flow therein. When, however, signals of a frequency at which the piezo-electric device will vibrate in resonance are impressed thereon, the vibrations of the piezo-electric device will cause an alternating potential of considerably greater amplitude to be impressed upon the grid of the piezo-electric device and a positive half cycle of this potential will cause a pulse of current to flow in the plate circuit in the tube. This will induce a potential in the secondary of transformer 21 which will be impressed on the grid and cause it to become more positive, which will in turn cause more current to flow in the space current path of the tube. The condenser 26 will therefore be discharged in a pulse of current which will pass through the relay 25 and cause it to actuate its armature 27. Continued resonant vibration of the resonator 16 will cause additional pulses of current to flow through the relay 25 at the frequency of the vibrations of the resonator or at some sub-harmonic thereof.

In the operation of the device of Fig. 3 incoming signals are applied to space discharge tube 30 through the piezo-electric device 31. The grid of this tube is normally so biased that no current will flow in the space current path thereof. However, when the incoming signals are of a frequency at which the piezo-electric

device 31 will vibrate in resonance the vibration of the device will cause an increased potential to be applied to the grid of the tube and pulses of current will flow in the output circuit thereof. This current induces a voltage in the secondary of the transformer 36 which is applied to the second space discharge tube 40, which acts as an amplifier, and energizes the relay 41 in the output circuit thereof.

The operation of the device of Fig. 4 is the same as that of Fig. 2, the difference between the two circuits relating to the manner of coupling the incoming signals through the piezo-electric device 49 to the regenerative detector 52.

In the operation of the device of Fig. 5 incoming signals are applied through a plurality of piezo-electric resonators to a plurality of three electrode space discharge devices, which are so designed with respect to their circuit constants that normally no current will flow in their output circuits. Each of the piezo-electric devices may have a different resonant frequency, and when the incoming signals are of a frequency corresponding to any one of these resonant frequencies, the resonator which vibrates in resonance at that frequency will amplify the impressed signals and apply a potential to the grid such that space current will flow in the output circuit of the space discharge tube associated with that resonator, and energize the relay in this circuit. Since a piezo-electric resonator will ordinarily vibrate in resonance at a plurality of frequencies, one of which may be the same for different resonators, it is possible by means of the system disclosed in this figure to arrange apparatus which will be alternatively selective, on a frequency basis, of a given one or more relays as determined by the characteristics of their respective controlling resonators. That is, if signals of a certain frequency are impressed thereon, relays 79 and 81 may operate, at another frequency relays 80 and 81 may operate, and at some other frequency perhaps only one relay will operate, etc.

In the operation of the device of Fig. 6, incoming signals are impressed upon a pair of space discharge tubes arranged in parallel with respect to the secondary of the transformer 93. The currents in the output circuits of the tubes due to these signals will mutually balance out in the relay 106. A potential is likewise impressed from the secondary of the transformer 93 across the piezo-electric device 94 and by means of the second pair of electrodes adjacent to this device, these signals are impressed upon the two space discharge devices in push-pull relationship. When signals of a frequency remote from a resonant frequency of the resonator 94 are impressed thereon, the resultant voltage impressed upon the grids of the tubes will not be sufficient to cause the relay 106 to be operated.

The voltage impressed on the grids by the resonator may be considered to be in phase with the displacement in the piezo-electric device for all frequencies, and the displacement in the device may be considered to be in phase with the driving voltage for all frequencies except the resonant frequencies of the device, and frequencies very close thereto. As the incoming frequency is gradually increased through a resonant frequency of the device the voltage impressed on the grids of the space discharge tubes due to the vibration of the device varies in proportion to the variations in amplitude of

vibration. As the incoming frequency passes through its resonant frequency there occurs a very rapid phase shift of the displacement in the device with respect to the phase of the applied voltage, and a corresponding shift in the phase of the voltage applied to the grids of the tubes with respect to the voltage applied to the device. At the resonant frequency of the device the phase of the displacement, and hence of the voltage generated thereby, is in quadrature with the voltage applied to the grids from the transformer 93. As the frequency of the incoming signals is gradually increased toward the resonant frequency of the device this phase shift, and the increased amplitude of the voltage due to the piezo-electric device, creates an unbalance in the currents flowing through the relay 106 and causes it to operate its armature in a direction corresponding to the sense of the unbalance. At the resonant frequency, the phase of the vibrating device is in quadrature with the applied voltage, there is again a balance in the current through the relay 106, and the armature is released. As this resonant frequency is passed the phase of the vibrating device continues to shift further in the same direction and there is again an unbalance in the relay current in the opposite sense and armature 109 is operated in the reverse direction to its previous operation. These operations of the armature may be used in any way desired. They may be caused to give a signal or to control associated apparatus. Purely for the sake of illustration it might be noted that on one contact a red light might be caused to light, at resonance there may be no signal, and on the other contact a green light might be caused to light.

The operation of the device of Fig. 7 is substantially the same as that of Fig. 6. Its operation over the critical frequency range is the same as that of the circuit disclosed in U. S. Patent 1,547,217, July 28, 1925, to J. Herman, the piezo-electric resonator 116 in Fig. 7 being equivalent to the source of voltage impressed on the secondary windings of transformer 18 in the Herman patent. In this figure the incoming signal is impressed upon the pair of space discharge tubes through the transformer, with respect to which their input circuits are arranged in push-pull relationship. The same signals are impressed upon the input circuits of the tubes through a piezo-electric device, and the input circuits of the tubes are in parallel relationship with respect to this device. In this case, the pulses of current due to the signals impressed upon the transformer 112 balance out as before and the potential applied to the grids due to the vibration of the piezo-electric device when signals of corresponding frequencies are impressed thereon, will cause the relay 124 to be operated as in Fig. 6.

It is to be understood, of course, that this invention is not confined to the particular devices or circuit arrangements shown, these being merely symbolic of a number of methods of accomplishing the same object. For example, the piezo-electric resonator disclosed herein may be replaced by any mechanical vibrating element such for example, as a tuning fork. The neon tube may be replaced by an argon tube or a tube filled with other suitable gas. The space discharge devices may have any number of electrodes and there are numerous circuit variations possible.

What is claimed is:

1. In combination, a neon tube, a source of energy in circuit therewith having an electromotive force insufficient to cause said neon tube to break down, and a piezo-electric device also in circuit with said neon tube, said piezo-electric device being adapted, when excited, to cause an increase in the electromotive force applied to said neon tube sufficient to pass current through said tube.

2. A relay having an incoming circuit and an outgoing circuit, a piezo-electric device associated with said incoming circuit and adapted to be excited thereby, an electric discharge device connected to said piezo-electric device, a regenerative circuit connected to said electric discharge device, and means normally subjecting said electric discharge device to an electromotive force insufficient to cause appreciable current to flow therethrough, and a circuit closer in said outgoing circuit energized by current traversing said electric discharge device whereby incoming energy in said incoming circuit excites said piezo-electric device to cause current to pass said electric discharge device and operate said circuit closer.

3. In combination, a space discharge device, a regenerative circuit connected thereto, a piezo-electric resonator and a circuit closer in circuit therewith, means for preventing the flow of current in the space current path of said device, and means responsive to signals impressed upon said piezo-electric resonator to cause current to flow in the space current path of said device.

4. A piezo-electric alternating current relay comprising a piezo-electric resonator, a space discharge device, a normally inoperative regenerative circuit connected thereto, a circuit closer in the output circuit of said device and a means independent of said regenerative circuit for impressing on said resonator an electromotive force wave having a frequency corresponding to a resonant frequency of said resonator and an electromotive force insufficient to cause regeneration in said circuit.

5. A piezo-electric relay, comprising a piezo-electric resonator, a regenerative detector, and a circuit closer, and means coacting with said detector to make it regeneratively oscillate whereby said circuit closer operates in response to signals of a resonant frequency of said piezo-electric resonator.

6. In combination, a regenerative detector having input and output circuits, a piezo-electric crystal in said input circuit, a relay in said output circuit, and means for impressing an alternating current potential on said input circuit which is insufficient to cause said detector to regenerate and having a frequency corresponding to a resonant frequency of said crystal.

7. In combination, a circuit including a piezo-electric crystal, a negative resistance device, and a relay operable in response to the operation of said negative resistance device, and means for impressing an alternating current potential on said circuit of the resonance frequency of said piezo-electric crystal, whereby said circuit is set into oscillation and said oscillations continue after the removal of the potential of said resonance frequency.

8. In combination, a relaxation oscillator and a piezo-electric crystal and means for triggering off said oscillator in response to impulses of the resonance frequency of said crystal.

9. In combination, a source of signals, and a circuit comprising a regenerative detector and a relay, means for coupling said source of signals to said circuit, and piezo-electric means for amplifying said signals at a desired frequency corresponding to a resonant frequency of said means sufficiently to cause said circuit to regenerate on the incidence of said signals. 80

10. In combination, a source of signals, and a

WARREN A. MARRISON.

10	85
15	90
20	95
25	100
30	105
35	110
40	115
45	120
50	125
55	130
60	135
65	140
70	145