July 14, 1942. J. P. ARNDT, JR 2,289,954

LEAKAGE REDUCING MEANS

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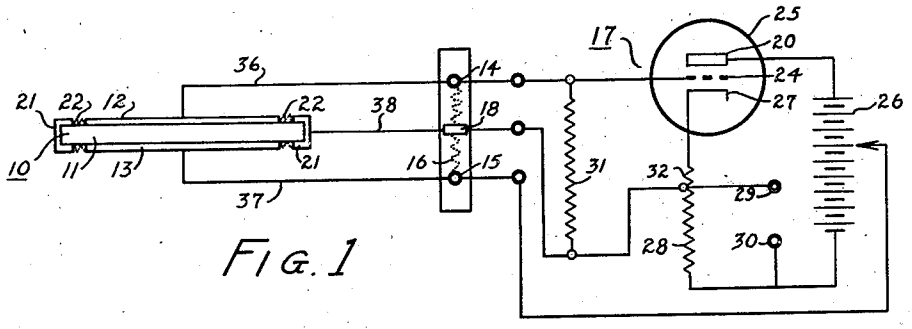


FIG. 1

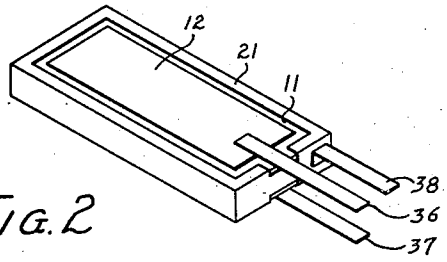


FIG. 2

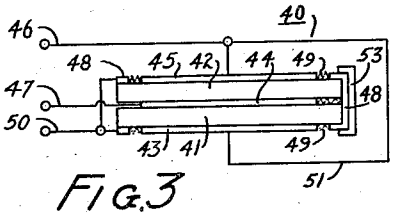


FIG. 3

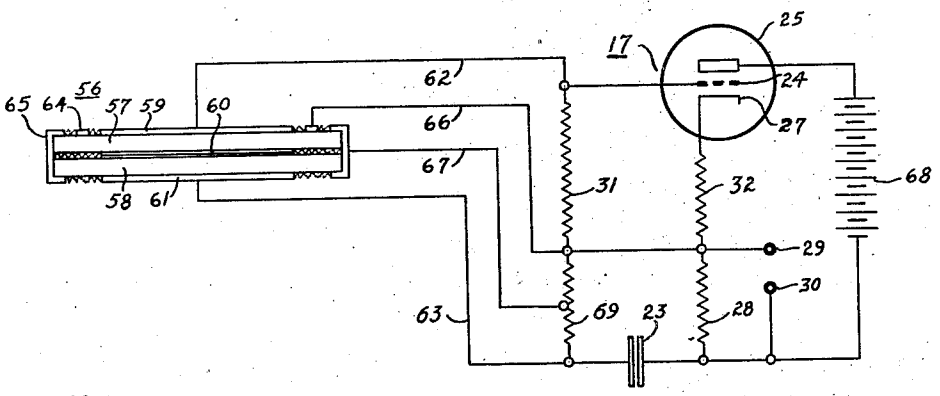


FIG. 5

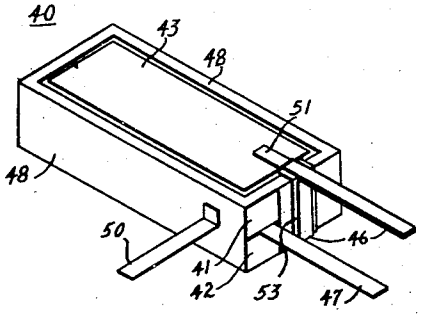


FIG. 4

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LEAKAGE REDUCING MEANS

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FIG. 6

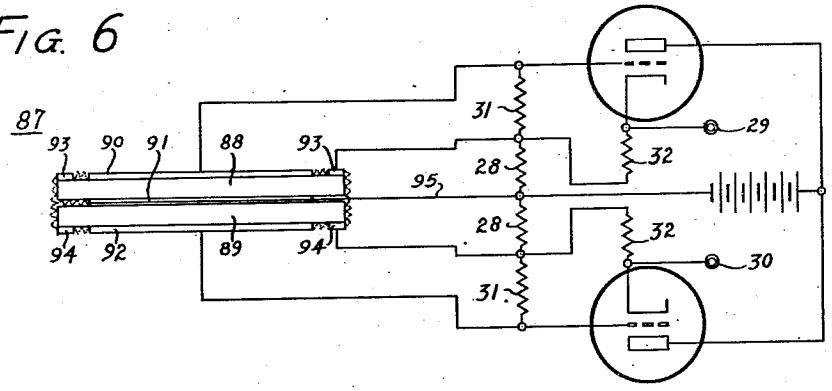
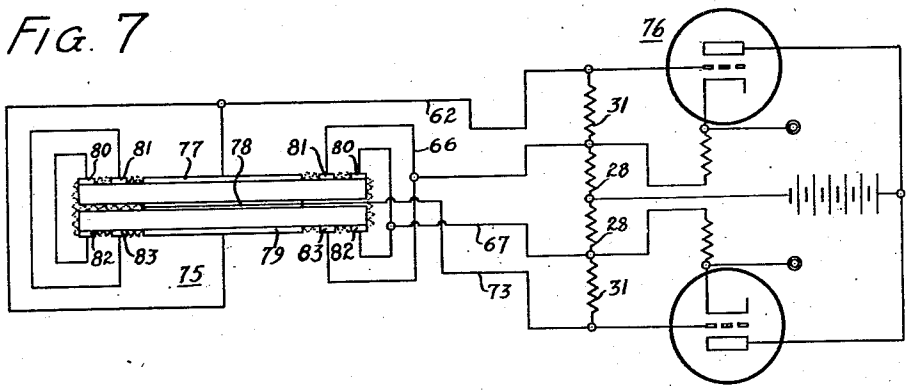


FIG. 7



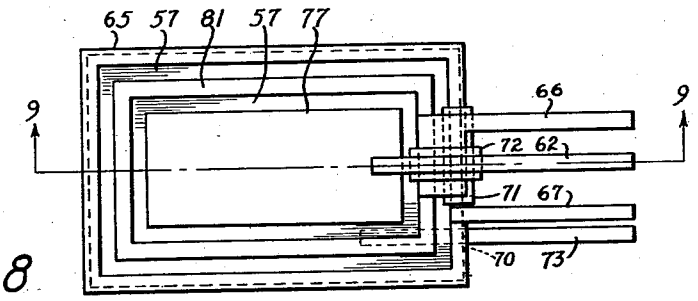


FIG. 8

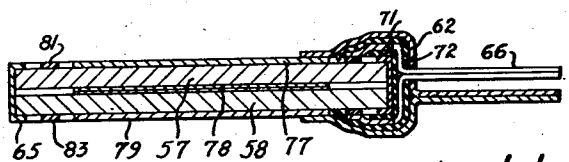


FIG. 9

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UNITED STATES PATENT OFFICE

2,289,954

LEAKAGE REDUCING MEANS

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Application January 8, 1942, Serial No. 425,962

19 Claims. (Cl. 179—1)

This invention relates to a method and apparatus for improving the performance of high impedance alternating current signal generators, and it relates more particularly to a method for mitigating the effects of signal current leakage in generators of the type described.

High impedance signal generators, of which the piezo-electric unit is an example, find many commercial applications, but are restricted in their usefulness by the fact that they are essentially voltage generators rather than current generators. This will be understood when it is recognized that if current is drawn from the generator, much of its generated voltage will be developed across its high internal impedance and little will appear at the generator terminals. On the contrary, if no current is drawn from the generator, all of its generated voltage will appear at the terminals, and will be available for use. This limitation in high impedance generators has long been recognized, and is kept in mind in designing the load circuits to which such generators are connected. Thus, if the generator is to be connected to a vacuum tube amplifier, it is customary to design the amplifier to have a high impedance input circuit. If the latter impedance is at least as high as the internal impedance of the generator, adequate signal voltage will ordinarily be obtained in the input circuit to control the amplifier. As the input impedance is increased in relation to the impedance of the generator, more voltage becomes available for use in controlling the amplifier. If the input impedance is made very large compared with the generator impedance so that very little or no current is drawn from the generator, the maximum amount of control voltage is made available. Amplifiers having extremely high input impedances, approaching infinite values, have become a reality through the invention disclosed in the copending application of J. P. Arndt, Jr., Serial Number 370,773, filed December 19, 1940, now Patent No. 2,288,600, so that it now is possible to connect high impedance generators to amplifiers which draw little or no current from the generator. A problem then became apparent and was partially solved by Walter J. Brown by his invention, Leakage reducing means, Serial Number 381,159, which will issue as Patent Number 2,282,319. The problem was that the advantages of a combination high impedance generator and an amplifier which draws little or no current from the generator could not be realized to their fullest extent if the generator had stray leakage paths of finite impedance. Such leakage paths are, of course, in shunt with the generator and with the impedance of the input circuit of the amplifier. Consequently, such leakage paths act as load circuits which draw current from the generator, and thereby defeat the objects sought to be accomplished through the use of the high impedance load, or input circuit. However, through the invention of Walter J. Brown it is possible to treat certain leakage paths in a manner which mitigates, and in many instances avoids, the detrimental effects of such leakage currents.

Upon combining the Arndt invention and the Brown invention it became apparent that for piezoelectric generators the controlling factor in the limitation of the device had become current leakage across the faces of the crystal generator. The present invention is a means and method of reducing leakage paths at the faces of the generator, and finds great usefulness in combination with the Brown invention for use with the Arndt invention, Serial No. 370,773.

The advantages of the present invention are particularly useful in connection with electrostatic generators such as condenser and electret microphones, and piezoelectric units and devices. Such electrostatic devices are inherently of a capacitive nature, whereas the leakage paths are essentially resistive. The result is that the leakage currents introduce an undesired low frequency cutoff. That is, for alternating current signals within a wide range of frequencies, the internal impedance of the generator may be sufficiently low compared with the resistance of the leakage path that the leakage currents do not materially reduce the voltage which is available at the generator terminals. At frequencies below this range, however, the internal impedance becomes so high that the leakage currents cause most of the generated signal voltage to be developed across the internal impedance, and very little to appear at the terminals. In consequence thereof, the generator becomes less effective as a generator of these low frequency signals. By means of this invention, however, the effective impedance of the leakage paths of the generator can be raised high enough to substantially avoid their effects, with the result that the generator may be worked at much lower frequencies.

The effectiveness of the present invention in connection with the electrostatic generators is illustrated by the sound cell microphone such as that disclosed in Sawyer Patent No. 2,105,010 and Williams Patent 2,126,438. Inasmuch as the output of each piezoelectric unit in the sound cell is

relatively small, it is usually necessary to connect a plurality of the units in series. The series connection results, however, in a small capacity for the microphone and thus requires a high input impedance in the amplifier for satisfactory low frequency response. However, the various leakage paths in the generators in such a microphone are apt to have impedances which are lower in value than the impedance of the microphone output circuit and the amplifier input circuit. Consequently, the generator surface leakage paths may determine the cutoff frequency and defeat the advantages which might have been gained through use of the high impedance input circuit. In the past, this difficulty has been overcome to some extent by connecting in parallel a plurality of such series-connected piezoelectric units. Such construction has been found to introduce acoustical errors since it increases the size of the microphone. By means of the present invention it is possible to increase the effective resistance of the generator surface leakage paths to the point where it is no longer necessary to resort to the use of multiple sets connected in parallel. Accordingly, the invention makes it possible to avoid many of the acoustical errors mentioned above, and to place the cutoff frequency at a lower frequency than could, in many cases, be obtained by placing a number of sets in parallel.

The invention is also of commercial importance in connection with low frequency devices such as pressure pickups of the type disclosed in Gravley Patent No. 2,207,539, since by avoiding the effects of stray leakage paths, the pick-up may be made to respond to very slow fluctuations in pressure. In instruments of this type, leakage has heretofore been a serious limiting factor in obtaining low frequency response because of the cutoff frequency which is imposed on the device by the leakage.

In view of the foregoing brief description of the invention, it will be understood that it is one object of the invention to provide a method and apparatus for decreasing the undesired effects of stray leakage paths on the surface of generators by increasing the effective resistance of all or certain of them.

It is another object to lower the cutoff frequency imposed on high impedance generators by all or certain of their stray leakage paths.

It is still another object to improve the performance of high impedance generators of the multiple type by raising at least the effective low-frequency impedance of the leakage paths which impose a cutoff frequency upon the generator.

It is a further object of the invention to use the out-put of an amplifier to raise the impedance of a leakage path of a high impedance generator whose signal controls the amplifier.

These and other objects will be apparent from the following detailed description of the invention taken in connection with the accompanying drawings.

Figure 1 illustrates the fundamental principles of my invention through a symbolic representation of a high impedance generator of the single slab piezoelectric type connected to an amplifier.

Figure 2 illustrates in detail a method of applying my invention to a generator of the single slab type.

Figure 3 illustrates symbolically my invention applied to a two-slab generator.

Figure 4 illustrates in detail a method of applying my invention to a generator having more than one slab.

Figure 5 symbolically represents a generator having a plurality of slabs connected to an amplifier.

Figure 6 symbolically represents a series connected generator having a plurality of slabs and associated with a push-pull amplifier.

Figure 7 symbolically represents a parallel connected generator connected to a push-pull amplifier.

Figure 8 is a plan view of a generator showing the electrodes and guard rings.

Figure 9 is a sectional view taken along line 9—9 of Figure 8, and showing details of insulation of the electrodes and guard rings.

Referring now to Figure 1, a high impedance generator 10 comprising, for example, a single slab 11 of piezoelectric material such as Rochelle salt, and electrodes 12 and 13, supplies signal potentials to terminals 14 and 15. A conductive stray leakage path between terminals 14 and 15 is illustrated symbolically by the resistance 16, and a suitable load such as the amplifier 17 is connected to the terminals 14, 15. From what has been said above, it will be understood that since generator 10 has a high internal impedance, it is necessary that the load, such as amplifier 17, have an impedance which is maintained high relative to the impedance of the generator if best performance is to be obtained. The adverse effects upon the generator 10 which were introduced by the leakage path 16 have been materially reduced and in some cases obviated by the invention of Walter J. Brown, Patent Number 2,282,319, which maintained the effective value of resistance 16 high relative to the impedance of generator 10. This was done by inserting a guard electrode 18 between the terminals 14 and 15, and maintaining the guard 18 at substantially the instantaneous potential of terminal 14.

In order to obviate or reduce the signal current leakage paths which exist across the surfaces of a piezoelectric generator, I provide the generator 10 with a guard ring 21 which extends entirely around and in contact with the edge of a single plate generator. The guard ring 21 intercepts the leakage path 22 which exists between the electrodes 12 and 13, and is connected to an amplifier or an auxiliary generator to maintain the guard ring 21 at substantially the instantaneous potential of the electrode 12. When this condition is met completely, there is no potential difference between the electrode 12 and the guard ring 21, and the result is that no current will flow between them. The effective resistance of the leakage path will then be infinite. This follows from the fundamental relationship between resistance, voltage, and current expressed by $R=E/I$ where E is the potential difference which exists at any instant between electrodes 12 and 13, and where I is the current flowing between electrodes 12 and 13 through the leakage path at the instant E is measured, and R is the effective resistance of the leakage paths. When the guard ring 21 is maintained at the same alternating potential as the electrode 12, there is no potential difference tending to cause a current to flow between them. The current I is accordingly zero, and R then equals E/O, and is infinite. If, however, at the same instant the instantaneous potential of the guard ring 21 is slightly less than the potential of electrode 12, a potential gradient exists between the

electrode and the guard ring 21 and some signal current will flow. The effective resistance of the leakage path may remain high, although being of a finite value, if the current I is sufficiently small. That is, if the potential difference between the electrode 12 and guard 21 is reduced appreciably below the value which it would have if the guard 21 were disconnected from the generator 10, then the effective resistance of the leakage path 22 will have been increased. It will be appreciated that the physical state of the leakage path, and hence its actual resistance, is not affected by the invention even though its effective resistance as seen by the generator is increased in the manner just explained. From what has been said above, it will be understood that when the potential gradient has been suitably adjusted, the signal current flowing in the path may be reduced, and the effective resistance of the path, as seen by the generator, will have been increased. Accordingly, it is of no significance that the path itself remains conductive, since the flow of current in the path may be controlled by the potential gradient which exists between the termini of the path.

My invention and Walter J. Brown's invention find their maximum usefulness when used together although for many applications they may be used separately. In Figure 1 they are shown used together and reference character 18 represents guard 8 of Figure 1 of the Brown patent.

It should be remembered that generator 10 supplies an alternating current signal; the potentials of the electrodes 12 and 13 consequently fluctuate or alternate between positive values and negative values in accordance with the frequency characteristics of the signal. If the potential of guard 21 is to be held at exactly the potential of electrode 12, it is obvious that the potential of the guard must likewise fluctuate in exactly the same manner as the potential of the terminal. In other words, the potential of guard 21 must be continuously in exact phase relationship with the potential of the electrode 12 and of the same magnitude. When this condition prevails, the two potentials will be in fully opposed phase relationship so far as current is concerned, since no signal or leakage current will flow between them. It will be understood that if the potentials are not in such exact phase relationship, guard 21 may reach the same maximum potential as the electrode but at a different instant. Under these conditions there will be an alternating potential difference between the two points and a signal current will flow between them. The same result occurs if the potentials are in phase but of different magnitude. The fact, however, that a signal current flows between them does not signify that the invention is ineffective in accomplishing its objects since the current which flows when generator 10 is in operation may be less than the current which flows when the guard 21 is disconnected from the generator 10. Any reduction in the leakage currents on the surface of generator 10 accomplished through the use of potentials of opposed phase relationship represents an improvement over conditions which prevail without the invention. The signal current which flows between electrodes is in the nature of surface leakage, and the surface guard rings which are positioned on the surface of the crystal are designed to intercept substantially all of the leakage current. In general the surface leakage problem is much more serious than the internal current leakage problem.

It will be appreciated that in practice it is somewhat difficult to employ a separate generator as the auxiliary source of guard voltage where the close phase relationship explained above must be maintained. This method was fully explained in connection with Figure 1 of the Brown patent. Although it is possible to synchronize two generators, it is generally more expedient to use an amplifier 17 as the auxiliary generator. That is, the high impedance generator 10 may be connected to an amplifier in such manner that the generator signal controls the input of the amplifier. The output signal of the amplifier may then be used in whole or in part to supply the guard potentials. When an amplifier is used in this manner, the close phase relationships which are required in practicing the invention may be maintained quite readily.

The amplifier 17 to which the generator 10 is connected is of the high input impedance alternating current type, as described in my application, Serial Number 370,773. The signal generator 10 supplies alternating signals to its terminals 14 and 15. Terminal 14 is connected to the grid 24 of the amplifier tube 25, and terminal 15 is connected through battery 26 to the plate 20 of tube 25. A plate circuit coupling resistor 28 and bias resistor 32 are provided between the battery 26 and the cathode 27. The output of the amplifier is obtained between terminals 29 and 30 and represents the signal current drop across the resistor 28. A grid leak resistor 31 is provided between the grid 24 and the negative side of bias resistor 32. The output signal across terminals 29 and 30 is in circuit with grid leak resistor 31 and the signal developed between electrodes 12 and 13; and its polarity is such as to oppose the signal between electrodes 12 and 13. Accordingly, there is little signal potential difference between the ends of the grid leak resistance 31 with the result that little current is drawn by the amplifier from the generator. The effective impedance of the amplifier is therefore relatively high.

Figure 1 shows by way of schematic representation that signal current leakage path 16 exists between terminals 14 and 15, and signal current leakage paths 22 exist on the surface of the generator 10. In order to increase the effective resistances of these leakage paths, the guard electrode 18 is positioned between terminals 14 and 15, and the guard ring 21 is positioned on the surface of the generator 10 between the electrodes 12 and 13. In this position the guard ring intercepts all or substantially all of the current leakage on the surface of the generator. The guards 18 and 21 are connected together and to the cathode end of resistor 28. Therefore, output voltage of the amplifier is applied between termini of a portion of each leakage path. As a result, the signal voltage which exists across the balance of each leakage path represents the difference between the generator voltage and the output voltage of the amplifier, and is much smaller than the voltage which would exist across it if the amplifier output were not so applied to the paths. Therefore, the leakage current supplied by the generator is proportionately reduced, and accordingly the effective impedance of each path as seen by the generator is proportionately increased. Leakage paths from terminal 15 to shield 18 and from electrode 13 to guard ring 21 would be in

parallel with the comparatively low impedance output circuit of the amplifier and therefore have negligible effect on the action of the circuit.

It will be recognized that the output signal obtained at terminals 29, 30 must necessarily be somewhat less than the signal potential applied to the amplifier at terminals 14 and 15. Accordingly, a small signal potential difference must exist between the grid 24 and output terminal 29, with the result that leakage currents will flow in the grid leak 31 and in the partial leakage paths which shunt the grid leak. In other words, it is not possible to reduce the leakage current to zero (and thereby to obtain in effect an infinite resistance in the leakage paths) with the amplifier which is illustrated in Fig. 1. Nevertheless, the design of the amplifier can be chosen so as to make the potential difference between the grid 24 and terminal 29 quite small. For example, it is easily possible to have this potential difference less than one-tenth the voltage between electrodes 12 and 13. This signifies, of course, that if guard ring 21, for example, is positioned so as to divide leakage path 22 into two equal parts, the effective resistance of the leakage path will have been increased more than five times.

It is a feature of the amplifier circuit of Fig. 1 that the direct current plate voltage is prevented from reaching the signal generator 10. This is accomplished by connecting terminal 15 to a tap on the battery 26 having the same D. C. potential as the grid leak 31. This feature and other circuit arrangements for accomplishing the same result are more fully discussed in the J. P. Arndt, Jr., application, Serial No. 370,773. Inasmuch as piezoelectric generators should not be subjected to biasing direct current voltages, it will be recognized that this feature of the circuits makes them particularly useful in combination with piezoelectric generators.

Figure 2 illustrates in detail the generator 10, and shows the electrode 12 in place on the top surface thereof. The electrode 13 is positioned on the bottom of the crystal slab 11, and the lead 37 engages it. Lead 36 engages (or may be integral with) the top electrode 12. The guard ring 21 is shown as engaging the edge surfaces, a little of the top surface, and a little of the bottom surface. It is to be understood, however, that this is for reasons of convenience in assemblying the unit and that the guard ring 21 may engage only one surface so long as it intercepts a large portion of the path between the electrodes 12 and 13. The electrodes 12 and 13 and the guard ring 21 may be of metal foil or of "Grafoil" type which is a graphite surface coating. For a more complete description of "Grafoil" electrodes see Williams' Patent, No. 2,106,143.

A lead 38 is connected to the guard ring 21 and adapted to be connected to the guard electrode 18, or directly to the cathode end of resistor 28. At the area where the leads 36 and 37 leave the crystal slab 11 the guard ring is cut away to prevent contact from being made between the lead and the guard ring. Another method of effecting the same result would be to apply separate insulation members between each lead and the guard ring 21. Either method is simple and effective.

Figure 3 illustrates symbolically a two-ply crystal generator 40 comprised of a first crystal slab 41 and a second crystal slab 42, and three electrodes 43, 44, and 45. The unit is parallel connected; that is, electrodes 43 and 45 are electrically the same and have a common lead 46, and electrode 44 has a lead 47. A guard ring 48 is provided around the edges of the two crystal slabs in the leakage paths between the electrodes 43 and 44 and between electrodes 44 and 45. In this position current leakage on the crystal surface between the electrodes of different polarity is intercepted. A lead 50 is connected to the guard ring 48 and to the guard electrode 18. The lead 47 is connected to the terminal 14, and the lead 46 to the terminal 15. Terminals 14 and 15 and guard electrode 18 may be connected to an amplifier 17 as is shown in Fig. 1.

Figure 4 illustrates in detail the generator 40, and shows the electrode 43 in place on the top surface thereof. The electrode 45 is positioned on the bottom of the crystal slab 42 and the electrode 44 is positioned between the slab 41 and the slab 42. A lead 51 engages the electrode 43, and a lead 46 engages the electrode 45. As the electrodes 43 and 45 are electrically the same in a parallel connected element the two leads 51 and 46 are joined and brought out as a single lead numbered for convenience 46. The guard ring 48 is positioned on the edges of both crystals slabs 41 and 42 substantially entirely around the unit. A small opening in the guard ring 48 is made at the point where lead 47 is brought out from between the slabs 41 and 42. Around the top surface of the slab 41 and around the bottom surface of slab 42 the guard ring 48 extends unbroken. The ring 48 is therefore positioned between electrodes 43 and 44, and between electrodes 44 and 45 where it will intercept substantially all surface leakage paths. An insulator 53 is provided between the guard ring 48 and the leads 46 and 51 to prevent contact therebetween. As in the single plate element 10 the electrodes and guard ring may be of the foil, "Grafoil," or any other type.

Figure 5 illustrates a series connected generator 56 comprised of a plurality of crystal slabs 57 and 58, and electrodes 59, 60, and 61 positioned on the faces of the crystal slabs 57, 58. A lead 62 is connected to the electrode 59, and a lead 63 is connected to the electrode 61. The electrode 60 may be in two parts, each part being connected to a slab of crystal, and is not connected to an external circuit and may be dispensed with. However, it usually is provided so that the electrostatic field need not traverse the cement used to secure the plates together. During operation the three electrodes will be at three different potentials. Accordingly, to reduce surface leakage to a minimum, two guard rings may be necessary. The first guard ring 64 may be positioned on the surface of one of the crystal faces. As illustrated it is positioned on the top face of crystal slab 57 and it extends entirely around the crystal so that it intercepts substantially all of the current leakage which tends to flow between electrode 59 and electrode 60. The second guard ring 65 is positioned on the edges of both of the crystal slabs 57 and 58 where it will intercept current leakage between electrode 60 and the guard ring 64, and current leakage between electrode 60 and electrode 61. A lead 66 is connected to the first guard ring 64 and to the cathode end of resistor 28 to establish the guard ring at a potential as near as possible to the potential of electrode 59 so that leakage between them will be at a minimum. A lead 67 is connected to the second guard ring 65 and to a resistor 69 which establishes a voltage dividing

network across output terminals 29 and 30. The point at which lead 67 connects to the resistor 69 is chosen to establish at the guard ring 65 a signal potential as near to the potential of the electrode 60 as practical. There may then be leakage between guard ring 64 and guard ring 65 but it is supplied by the low impedance output of amplifier 17 and accordingly is of little consequence. Likewise, leakage between guard ring 65 and electrode 61 will be supplied by the amplifier 17. As the guard ring 65 is maintained at an instantaneous potential substantially the same as the instantaneous potential of the electrode 60 there will be substantially no tendency for leakage between these two points. As was explained in detail in the Brown patent, slight phase shift is not seriously detrimental and in some instances may be corrected by appropriate circuits.

Figure 7 illustrates a parallel connected element 75 connected to a push-pull amplifier 76. The element 75 has electrodes 77, 78, and 79; and has two guard rings 80, 81 in the leakage path between the electrodes 77 and 78, and two guard rings 82, 83 in the leakage path between the electrodes 78 and 79. The guard rings 81 and 83 are electrically the same and extend substantially entirely around the unit, and the guard rings 80 and 82 are electrically the same and extend substantially entirely around the unit. The rings are shown in this manner as it may be considerably easier to spray graphite on the surface of a crystal with certain portions masked out to establish electrode 77 and guard rings 80, 81 all in one operation. Guard rings 81, 83 are connected to the cathode end of resistor 28 of one tube at a point to establish a potential in the guard rings which is nearly the same as the potential which exists on the electrodes 77, 79 to reduce the leakage between the electrodes 77, 79 and the guard ring 81, 83 to a relatively small value. The guard rings 80, 82 are connected to the cathode end of resistor 28 of the other tube at a point to establish a potential in the guard rings which is substantially the same as the potential which exists on the electrode 78 to reduce the leakage between the electrode 78 and the guard rings 80, 82. Leakage between guard rings 81, 83 and 80, 82 will be supplied by the amplifier.

Figures 8 and 9 illustrate in detail a generator somewhat similar to the generator 75 and shows a manner in which the leads and guard rings may be insulated from each other. If the second guard ring 65, which is electrically the same as guard rings 80, 82 of Figure 7, extends over the side faces of the element, an opening 70 is provided in the said second guard ring and the lead 73 extends through it. Lead 73 is connected to electrode 78. An insulator 71 is positioned between the second guard ring 65 and the lead 66, and an insulator 72 is provided between the lead 62 and the lead 66. The insulator 72 should be broad enough to extend over both the first guard rings 81, 83 and the second guard ring 65 (80, 82 of Fig. 7).

Figure 6 illustrates a series connected generator 87 comprised of a plurality of crystal slabs 88, 89 and a plurality of electrodes 90, 91, and 92. Electrode 90 is connected to the grid of a first tube in the push-pull amplifier, and electrode 92 is connected to the grid of the second amplifier tube. A first guard ring 93 is positioned on the crystal slab 88 around the electrode 90 where it will intercept substantially all current leakage between electrode 90 and 91, and a second guard ring 94 is positioned on the crystal slab 89 around the electrode 92 where it will intercept substantially all current leakage between electrodes 91 and 92. The guard ring 93 is connected to the cathode end of resistor 28 for the first amplifier tube to maintain the guard ring 93 at a potential nearly that of the electrode 90, and the guard ring 94 is connected to the cathode end of resistor 28 for the second amplifier tube to maintain the guard ring 94 at a potential nearly that of the electrode 92. Current leakage between electrode 90 and guard 93 and between electrode 92 and guard 94 is therefore greatly reduced. The current leakage between the guard rings 93 and 94 will be supplied by the amplifier so it will not materially affect the generator 87. If the resistance of the leakage path from guard ring 93 to electrode 91 is not substantially equal to the resistance of the leakage path from guard ring 94 to electrode 91 then a central connection 95 from electrode 91 to the junction of the two cathode load resistors 28 may be put in.

It is to be understood that after the electrodes and guard rings have been applied to the surfaces of the crystal slabs that the unit may be covered with waterproofing material to prolong its life and render it more useful.

Reiterating, my invention chiefly concerns itself with building into a crystal element sufficient guard rings in accordance with the type of electrical connection and number of crystal plates and electrodes so that all surface current leakage paths are intercepted by guard rings; and to connect the guard rings to the output of an amplifier (whose input may be controlled by the generator) to introduce into the leakage paths signal voltage to oppose the flow of generator leakage current.

Although I have described my invention with a certain degree of particularity, it is to be understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction of the units may be made without departing from the spirit and the scope of the invention as hereinafter claimed, and that many circuit arrangements may be used with the different units.

I claim as my invention:

1. In a signal generator, a body of piezoelectric material adapted to supply a signal potential and having a signal current leakage path on its surface which conducts signal currents and thereby tends to reduce the signal available from said generator, guard means on the surface of the piezoelectric material and adapted to intercept substantially all of said leakage.

2. In a signal generator, a body of generating material, a plurality of electrodes connected to said body of material and between which a signal potential supplied by said body of material is adapted to exist, and between which there is a signal current leakage path on the surface of the body of generating material which conducts signal currents thereby tending to reduce the signal available from said electrodes, guard means on the surface of said body of generating material positioned between said electrodes and adapted to intercept substantially all of said leakage.

3. A signal generator comprising, in combination, a piezo-electric crystal plate, two electrodes on said crystal plate between which a signal potential is developed by piezoelectric action of the said plate, said crystal plate having a signal current leakage path on its surface between said

two electrodes which conducts signal currents and thereby tends to reduce the signal available from said electrodes, guard means positioned on said crystal plate to intercept said leakage, and lead means connected to said two electrodes and to said guard means.

4. A piezo-electric unit comprising, in combination, a piezo-active body having a pair of faces first and second electrode means disposed one on each of said faces, guard means connected to the surface of the piezoelectric body, and lead means connected to said first and second electrode means and to said guard means and adapted to connect said unit in a circuit.

5. A parallel connected piezo-electric unit comprising, in combination, a first slab of piezo-active material, a second slab of piezo-active material, central electrode means disposed between said first and said second slabs of piezo-active material and in conductive engagement with each, first outside electrode means in conductive engagement with said first slab of piezo-active material, second outside electrode means in conductive engagement with said second slab of piezo-active material, said unit having a signal current leakage path, guard means positioned on said piezo-active material and in said leakage path, first lead means connected to said outside electrode means, second lead means connected to said central electrode means, said first and second lead means being adapted to carry the current generated by said unit, and lead means connected to said guard means.

6. A series connected piezo-electric unit comprising, in combination, a first slab of piezo-active material, a second slab of piezo-active material, central electrode means disposed between said first and said second slabs of piezo-active material and in conductive engagement with each, first and second outside electrode means respectively in conductive engagement with said first and said second slabs of piezo-active material, each of said slabs having a leakage path between its outer electrode and its inner electrode, first guard means connected to the surface of said piezo-active material and in one of said leakage paths, second guard means connected to the surface of said piezo-active material and in the other of said leakage paths, lead means connected to said outside electrode means and adapted to carry the current generated by said unit, first guard lead means connected to said first guard means and second guard lead means connected to said second guard means, said first and second guard lead means being adapted to supply said guard means with alternating potential.

7. In combination, a high impedance signal generator element adapted to supply a signal potential and having a signal current leakage path on its surface which conducts signal currents and thereby tends to reduce the signal available from said generator element, guard means on the surface of the generator element, and voltage supply means connected to the guard means to reduce the flow of generator element signal current along said surface leakage path.

8. In combination, a high impedance signal generator element adapted to supply a signal voltage at its electrodes and having a leakage path which conducts signal currents and thereby tends to reduce the signal available from said generator element; and means for reducing the loss of signal resulting from said leakage, said means comprising at least one guard electrode disposed on said generator element and in said leakage path intermediate its electrodes, and an amplifier having an input circuit and an output circuit, said amplifier having its input circuit connected to the generator element electrodes and having at least a part of the output signal of its output circuit applied between the guard electrode and an adjacent point on the leakage path in opposed phase relationship to maintain voltage between said guard and point greater than the voltage established between them by the flow of said leakage current in said leakage path.

9. In combination, a high impedance signal generator element adapted to supply a signal voltage at its electrodes and having on its surface and in shunt with said electrodes a signal current leakage path which tends to reduce the signal available from said generator element; and means for reducing the loss of signal resulting from said surface leakage, said means comprising a pair of spaced guard electrode means disposed on the surface of said element and in said leakage path; and an amplifier having an input circuit and output circuit, said amplifier having its input circuit connected to the generator element electrodes and having at least a part of the output voltage of its output circuit applied between said guard electrodes to maintain said guard electrodes individually at substantially the instantaneous signal potential of the generator element electrode to which it is nearest.

10. In combination, a high impedance generator element adapted to supply an alternating current signal at its electrodes and having a signal current leakage path across its surface which conducts signal currents between the electrodes and thereby tends to reduce the signal available from said generator element; and an auxiliary source of signal connected in shunt with a fractional part of the leakage path, said auxiliary source being adapted to increase the signal-current potential-drop across said fractional part when connected in shunt therewith, and thereby to decrease the potential drops across the remaining parts of the leakage path.

11. The combination as claimed in claim 10 wherein the auxiliary source is the output of an amplifier whose input is connected to the high impedance generator element.

12. The combination as claimed in claim 10 wherein said auxiliary source is adapted to maintain the potential drop across said fractional part of the leakage path approximately equal to the potential drop which exists between the said electrodes when the leakage current flowing between them is zero, thereby to substantially eliminate signal potential drops across the remaining parts of the leakage path.

13. The combination as claimed in claim 10 wherein said fractional part of the leakage path extends from one electrode of the generator element to a guard electrode disposed on the surface of the generator element in said leakage path intermediate said electrodes.

14. The combination as claimed in claim 10 wherein said fractional part of the leakage path extends between a pair of guard electrodes disposed in said leakage path in spaced relation to each other and to the electrodes of said generator element.

15. In combination, a high impedance generator element adapted to supply an alternating current signal at its electrodes and having a signal current leakage path across its surface which conducts signal currents between said electrodes

and thereby tends to reduce the signal available from said generator element; and an auxiliary signal connected in shunt with a fractional part of the leakage path and in opposed phase relationship to the potential difference between its said electrodes.

16. The combination as claimed in claim 15 wherein said auxiliary signal is controlled by the high impedance generator.

17. In combination a signal generator element adapted to establish a signal potential difference between conductor means connected in a circuit, said generator element and said circuit each having a signal current leakage path which conducts signal currents thereby tending to reduce the signal available from said generator element; first guard means on the surface of said generator element and second guard means in said conductor leakage path, an amplifier having an input circuit and an output circuit, said amplifier having its input circuit connected to the signal output of said generator element and having at least a part of the output signal of its output circuit applied to said first and second guard means to reduce the flow of generator element signal current through said leakage paths.

18. In combination, a signal generator element adapted to supply a signal voltage to a circuit, said generator element having surface current leakage and said circuit having current leakage which together tend to reduce the signal voltage supplied to said circuit, first guard means associated with said generator element and second guard means associated with said circuit, and means connected to said first and said second guard means and adapted to utilize a portion of the generated signal voltage for applying to said first and said second guard means a potential to substantially reduce said surface current leakage and said current leakage in said circuit.

19. A signal generator comprising, in combination, a plate of piezoelectrically active crystal material adapted to supply a signal potential, first and second electrode means on surfaces of the piezoelectrically active crystal material, said crystal material having a signal current leakage path across its surface between said first and said second electrode means which conducts signal currents and thereby tends to reduce the signal available from the crystal material, guard means positioned on the surface of the piezoelectrically active crystal material and in the leakage path between the first and the second electrode means to intercept said leakage, first lead means connected to said first electrode means, second lead means connected to said second electrode means, and third lead means connected to said guard means, said first, second, and third lead means being adapted to connect said plate of piezoelectrically active crystal material into an electrical circuit.

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