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Oct. 25, 1966 H. W. SCHAFFT 3,281,726

PIEZOELECTRIC VOLTAGE TRANSFORMING DEVICE

Filed Oct. 10, 1963

FIG. 1

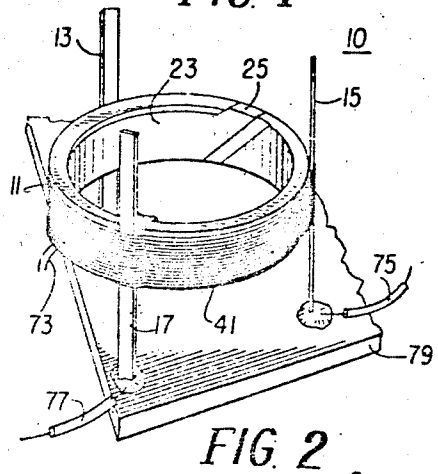


FIG. 3

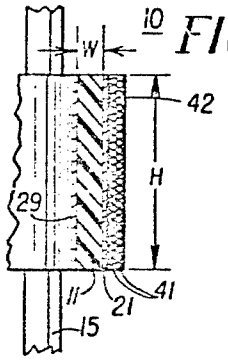


FIG. 4

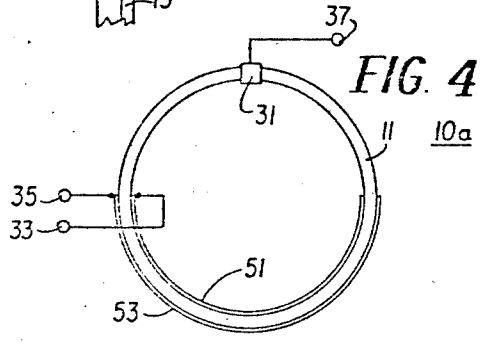


FIG. 2

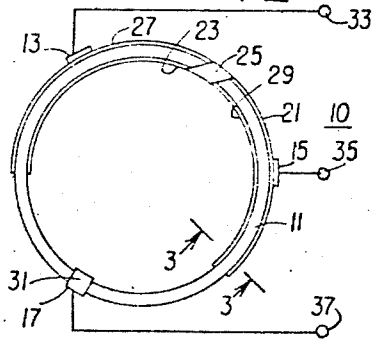


FIG. 7

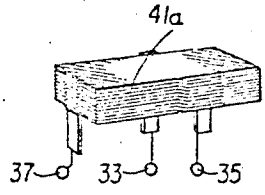


FIG. 5

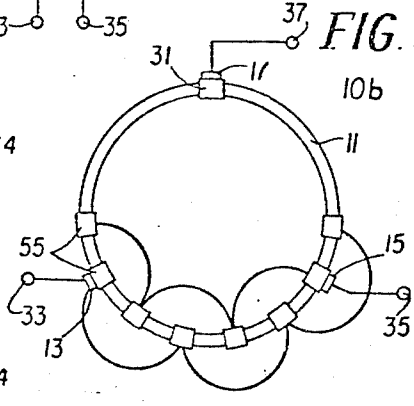
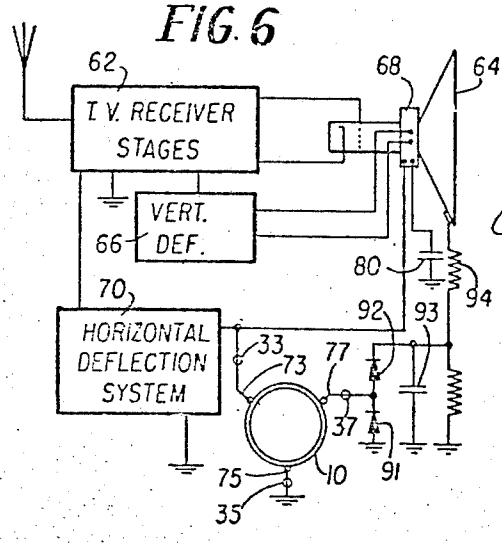


FIG. 6



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3,281,726

PIEZOELECTRIC VOLTAGE TRANSFORMING DEVICE

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10 Claims. (Cl. 333—72)

This invention relates to an electromechanical impedance transfromation device which may be used to produce a high potential wave from a relatively low potential energizing source, and to an improved construction for such a device which renders it capable of withstanding high energy driving signals. This application is a continuation-in-part of my copending application Serial No. 154,741, filed November 24, 1961, now abandoned.

There are various applications for high voltage transformation devices wherein a low voltage energizing wave is used to produce a very much higher voltage wave of modest current. For example, in a television receiver it is common to energize a voltage step-up system for the horizental deflection signals in the receiver in order to develop a wave which can be rectified to produce 20,000 volts of direct current, or more, for the screen of the cathode ray picture tube. Such a high potential requires a costly transformer and special construction to prevent voltage breakdown or arc over within the receiver. Furthermore, after aging of the high voltage insulation for some time, the insulation can deteriorate causing failure and reducing component life within the receiver.

An object of this invention is to simplify and reduce the cost of a high voltage transformation device.

A further object is to provide a novel and improved impedance transformation device.

Another object is to provide a reliable and sturdy high voltage transforming device.

A still further object is to provide an improved high voltage system for a cathode ray tube, such as used, for example, in a television receiver.

A feature of the invention is the provision of a transducer including a ceramic ring that resonantly vibrates in the hoop mode and has a rectangular cross-section of which the axial dimension equals or exceeds the radial dimension, or wall thickness.

A further feature of the invention is the provision of an annular piezoelectric transformer having two driving electrodes, each having a pair of plate portions respectively on the inside and outside of the ring to apply a field across the radial dimension thereof, and through Poisson's coupling, drive the ring in the hoop mode of vibration.

Another feature of the invention is the provision of an annular piezoelectric transformer having a plurality of alternately series connected electrodes spaced along a portion of the circumference thereof for applying a field to the transformer along its circumference and driving the same in the hoop mode of vibration.

Still another feature is the provision of resilient conductors attached to the electrodes on an annular ceramic transformer, which conductors also serve to mount the transformer in operative position.

A further feature is the provision of a piezoelectric ceramic ring with a dimension selected to resonate the ring at an integral frequency relation of the line deflection frequency in a televison receiver, and of electrode means for applying energy from the deflection system to the member and for deriving a high voltage wave to be rectified for the receiver picture tube.

Still another feature of the invention is the provision, on a transducer, of glass filament winding prestressing the transducer into compression along the direction of vibration thereof, which glass has a co-efficient of thermal

expansion substantially the same as that of the transducer material.

In the drawings:

FIG. 1 is a perspective view of a ceramic transformer constructed in accordance with the invention;

FIG. 2 is a top plan view of the transformer of FIG. 1;

FIG. 3 is a sectional view taken along the line 3—3 of FIG. 2;

FIG. 4 is a top plan view of an alternative embodiment of the invention;

FIG. 5 is a top plan view of still another embodiment of the invention;

FIG. 6 is a schematic diagram of a television circuit incorporating the invention; and

FIG. 7 is a perspective view of another embodiment of the invention.

In a particular form, the invention comprises an annular member which is composed of piezoelectric ceramic material. The circumference of the member is selected to support resonant hoop mode vibration of the member at a predetermined frequency. The member may be driven by an electric field varying at the resonant frequency of the member and produced by spaced electrodes on the member so that the field is developed in the direction of polarization of a driving area of the member. An output voltage wave is derived between electrodes spaced to embrace a region of the member which is mechanically stressed by the resonant vibration and which region is polarized in the direction of the vibration. In a highly efficient form of the device, the electrodes are arranged so that the electric driving field is in the direction of the resonant vibration and polarization of the entire member. The outer surface of the member may be clamped in compression, e.g. through winding with a glass filament which places the member under a prestressed state of compression. The glass has a coefficient of thermal expansion substantially the same as that of the ceramic so that variations in the amount of prestress are minimized. The transforming device is particularly adaptable for use in a high voltage system of a television receiver in which energy can be used from the horizontal deflection system to develop an output wave which can be rectified to produce 20,000 volts or more for the screen of a cathode ray picture tube.

Considering now FIGS. 1 through 3, there is shown the transforming device 10 comprising a ring or annular member 11 which is of tubular configuration and has conductors 13, 15 and 17 spaced at 120° intervals about the circumference thereof. The conductors are strips of resilient conductive material of sufficient strength to provide a mounting for the member 11. Accordingly, appropriate leads 73, 75 and 77, to be connected into the circuit to be explained subsequently, may be soldered directly to the conductors 13, 15 and 17 to provide electrical connections to the transformer. At the same time, the member 11 is supported on an insulated chassis 79 by the electrodes.

Conductors 13 and 15 are each electrically and mechanically connected to a pair of plate electrodes on opposite sides of member 11. Thus, conductor 15 is connected to a plate electrode 21 on the outside of member 11 and electrode 21 is, in turn, connected to electrode 23 on the inside of member 11 by a conductive strip 25. Similarly, conductor 13 is connected to an electrode 27 on the outside of member 11, and electrode 27 is connected to electrode 29 on the inside of member 11 by means of a conductive strip (not shown) over the bottom edge of member 11 which is similar to strip 25. Because of the inside-outside configuration of the electrode plates, conductors 15 and 13 may both be disposed on the outside of ring 11. This means they may easily be attached to the electrodes under a glass wrapping to be subsequently

explained. Conductor 17 is fastened to a band electrode 31 which surrounds a portion of member 11. Electrodes 21, 23, 25, 27, 29 and 31 may be deposited on the surface of the member 11 by electrolysis. Exciting signals for the transforming device are applied between the terminals 33 and 35 and an output voltage wave is derived at terminal 37 with respect to one of the input terminals which would be a common terminal.

The annular member on ring 11 is composed of a piezoelectric ceramic material such as a barium titanate or lead titanate zirconate, the latter being preferable to the former and being presently available under the designation PZT–4 from the Clevite Corporation of Cleveland, Ohio. The mean circumference of annular member 11 is selected to be one-half of the wavelength of the exciting signal or a harmonic thereof, that is, one-half of the wavelength of an integral multiple of the exciting signal. This will permit resonant vibration of ring 11 in the hoop mode with alternate expansion and contraction of the circumference. By utilizing the piezoelectric effect and driving the ring in the hoop mode at its resonant frequency of vibration the ceramic material is utilized most efficiently. In other modes of vibration nodal points are set up such that there are points of maximum stress and points of zero stress on the transducer. Voltage is generated only where the stress is maximum and accordingly if the nodal points or points of zero stress can be eliminated, the device will be more efficient. The hoop mode of vibration has no nodal points.

The input electrodes, respectively comprised of electrode portions 21 and 23 and electrode portions 27 and 29, define a motor or driving section for the portion of the ring between these electrodes. The tubular ring is polarized across the thickness or radial dimension thereof throughout the portion between the input electrodes so that the applied driving field is in the same direction as the polarization. Change in radial dimension of the portion between the input electrodes caused by the applied field will result in a corresponding change in circumference due to Poisson coupling. The spacing between the input electrodes and output electrode 31 defines generator or driven sections of the ring between the input electrodes and the output electrode 31 which are electrically in parallel and mechanically in series. The ring is polarized circumferentially along this distance so that this polarization is in the same direction as the resonant vibration in the hoop mode. Thus, there will be a strain along the circumference of the ring 11 throughout the driven section due to the resonant excitation of the ring to produce the output potential developed at electrode 31.

Since the ring 11 is an integral piece, the driven and output sections thereof are very tightly coupled. There are no joints or other breaks in the ceramic material along the ring, and its cross-section is rectangular for even field distribution. Even field distribution is desirable for efficient operation because when the distribution is uneven, only that material between the closest portions of the electrodes is utilized, and the rest is wasted. The same considerations make it desirable to keep the radial dimension W small with respect to the ring diameter. This minimizes variation in field distribution between output electrodes. The output current of the device 10 increases linearly with increase of the exciting frequency and also depends directly upon the area of the output electrode. The output voltage of the system is directly proportional to the distance between input and output electrodes and to the Q of the member. However, for efficiency it is desirable that the driving section be of greater length than the driven section (that the length of ring 11 between the electrodes 21 and 29 be greater than the length of ring 11 between the input electrodes 21, 29 and the output electrode 31), to make up for friction or conversion losses in the material.

There are numerous design considerations which have a bearing on the optimum proportions of the device. The input and output impedances are inversely proportional to the input and output capacities, respectively. The input capacity is proportional to the axial dimension H divided by the radial dimension W, since the capacity will be proportional to the area of the electrodes and inversely proportional to the distance between them. The output capacity on the other hand, is proportional to H times W, since it is directly proportional to the cross-sectional area between input and output electrodes. The output voltage of the transformer is directly proportional to the ratio of input capacity to output capacity. From the above relationships it may therefore be seen that the output voltage is also proportional to the inverse square of W. W however, must be of a value substantial enough to handle the power requirements of the device since the power capability of the device is directly proportional to the dimension W.

From the above relationships, the design of the device may generally follow this pattern. The input and output impedances required are first determined. There should be a slight mismatch of impedances both at the input and at the output for optimum efficiency. The mean diameter of the ring will be determined by the frequency at which it is desired to operate. The dimension W is then selected to be minimum according to the power handling capabilities desired. Then, values for the distance between output electrodes, the area of the input and output electrodes, and the dimension H are selected according to the desired voltage output and impedance requirements. It has been found that for optimum efficiency, H should be at least equal to W and preferably should be substantially greater than W. H, however, will be limited due to the fact that the more tubular the ring becomes, the greater the losses become due to vibrations set up in the longitudinal mode, that is, the axial direction. As a rough rule the dimension H would probably be no greater than one-fifth of the mean diameter of the ring.

Under certain circumstances, the voltage at the resonant frequency applied to the transformer might be sufficient to cause member 11 to exceed its structural capabilities and break. Accordingly, annular member 11 may be prestressed by means of a wrapping opposing the direction of maximum stress. Glass filament 41 is wound about the outer periphery of member 11. When a great number of windings are put on member 11, the ring may be prestressed to the point where member 11 will never go into the region of tensile stress in which breakage will occur. Ordinarily, ceramic materials and other magnetostrictive and electrostrictive materials are capable of much greater compressive stress than tensile stress. By use of glass filament 41, the member 11 may be prestressed to raise its effective tensile strength, while still retaining sufficient compressive strength and keeping internal losses at a low level. A satisfactory design approach is to determine the maximum tensile stress which will be placed upon the ring at the particular driving voltage being used. The prestressing should be applied to counteract this maximum force and offset it such that the ring never goes into a region of tensile stress. Since glass is nonconductive, no additional insulation is required. In the device shown in FIGS. 1–3, the glass wrapping also serves to hold the conductors 13 and 15 in place against their respective electrodes, resulting in a secure structure.

It is desirable that the glass have the same thermal expansion properties as the ring to maintain a relatively constant amount of prestress as ambient temperature varies. A quartz glass monofilament, of which there are several types available, is a satisfactory material. The winding may be covered with epoxy resin 42 to seal the spaces between the filaments and prevent damage thereto. The resin, however, should be as brittle as possible

to come as close to the elastic property of the glass because the resin could inhibit vibration and thereby reduce the efficiency of the transformer. Because the glass is of high elasticity compared with that of the ceramic, losses in the device due to the wrapping are minimal. The resonant frequency may be changed slightly, but this may be anticipated by proper design.

Of course, other types of transducers comprised of field strictive material (electrostrictive or magnetostrictive) could be prestressed in this manner. The wrapping should be applied to cause compression in the direction of vibration. For example, in FIG. 7, a rectangular block vibrating longitudinally is wrapped so that the glass yarn or filament 41*a* passes over its ends. This prestresses the block in the longitudinal direction to increase its ability to withstand high driving voltages at terminals 33 and 35.

In FIG. 4 there is shown a transforming device 10*a* which also utilizes ring shaped piezoelectric ceramic member 11 to be vibrated in resonance in the hoop mode. There are input electrodes 51 and 53 disposed respectively on the inside and outside circumference of the ring. These are connected to the input terminals 33, 35. Diametrically opposite the input electrodes 51 and 53 there is an output electrode 31 which completely surrounds the cross-section of the ring 11. This output electrode 31 is connected to the terminal 37. Throughout the region of ring 11 which is encompassed by the input electrodes 51, 53, the ceramic ring is polarized across the thickness of its wall so that the polarization is parallel to the applied field developed between these electrodes. In the region between the output electrode 31 and the ends of the input electrodes 51, 53, the polarization is arcuate along the circumference of the hoop between these points. The overall circumferential length of the ring 11 is selected with the same considerations as involved in selecting the dimensions in FIG. 3, and the other considerations for electrode spacings are like those involved in the device of FIG. 2.

Application of resonating input signals to the terminals 33, 35 of the device 10*a* produces hoop mode vibrations and straining of the ceramic ring 11 between the ends of the input electrodes and the output electrode to produce a high voltage sine wave at the output terminal 37 with respect to an input terminal.

It is also possible that the input electrodes be arranged in the form of a series of spaced strips extending around the ring, such as the arrangement of electrode strips 55 in the device 10*b* of FIG. 5. In this situation, alternate ones would be connected together and the polarization of the entire ring 11 would be circumferential. Poisson coupling is not necessary to drive the device of FIG. 5 because input polarization is circumferential and in the circumferential direction of vibration. This drives the device directly in the hoop mode with high efficiency. The embodiments of FIGS. 4 and 5 may also be stressed to withstand greater driving signals as previously explained.

FIGURE 6 shows a use of the transforming device 10 to provide the high voltage for the screen of the picture tube in a television receiver. The television receiver has receiver stages 62 which comprises a tuner, intermediate frequency amplifiers, a detector, and a video amplifier for driving the cathode ray picture tube 64. In addition, stages 62 may include the usual sound detector and loudspeaker system plus an automatic gain control system and a synchronizing signal separator to derive a vertical and horizontal synchronization signal from the received composite video signal. A vertical deflection system 66 is connected to a deflection yoke 68 on the neck of the cathode ray tube 64. The horizontal deflection system 70 is also properly synchronized by the means of the received synchronized pulses.

Deflection system 70 would include the usual horizontal or line deflection oscillator operative at a frequency of 15.75 kilocycles. From such an oscillator, which is synchronized, a waveform is developed from which sawtooth deflection current is derived and applied to the horizontal deflection windings of yoke 68. This circuit is completed to ground through capacitor 80.

The connection from horizonal deflection system 70 to the deflection yoke 68 is also connected to the input terminal 33 of transforming device 10, and the common terminal 35 is connected to ground. The voltage applied to terminal 33 is of pulse waveform having a repetition rate of 15,750 cycles. The voltage derived from the transformer device 10, however, is of sinusoidal waveform. The output terminal 37 is connected to a full wave rectifier comprised of series diodes 91 and 92 and capacitor 93. The full wave rectifier is connected through an isolation resistor 94 to the screen of the cathode ray picture tube 64.

In the television receiver of FIG. 6, it may be preferable to resonate the transforming device 10 at the second harmonic of the horizontal deflection frequency, namely 31.5 kilocycles. With the device constructed in this manner its energization signals will be well above the highest audible frequency and the device can be constructed of relatively small size. For example, a mean diameter of between one and one-quarter and one and three-quarter inches would probably suffice. There will usually be a sufficent amount of the second harmonic available at the output of the horizontal deflection system in order to insure proper energization of the device 10. While much higher resonant frequencies can be used, such higher frequencies would necessitate a smaller physical size of the device with the attendant problems of proper plating or other depositions of the electrodes, and of voltage breakdown among closely spaced electrodes of the device. When it is considered that rectified potentials of the order of 20,000 volts and even more are commonly applied to a picture tube, the problem of voltage breakdown can be appreciated. It is also possible to construct a device 10 to be resonant at the horizontal deflection frequency of 15.75 kilocycles, but this would require a relatively large physical size and might result in some audible vibration from the device. While it has been stated that the device 10 is constructed to be resonant at an exact integral multiple of the energizing frequency therefor, it should be understood that a resistive and/or capacitive load for the high voltage energization system will lower the resonant frequency of the device by a slight amount. Accordingly, it may be desirable that the resonance of the device 10 be a few percent higher than the frequency at which mechanical resonance occurs in order to compensate for this effect of the load.

In the transforming device 10*b* described in the foregoing, any one of which could be utilized in the system of FIG. 6, a piezoelectric ceramic member is utilized as a "motor" to resonantly drive a "generator" through electrostrictive action within the member. It is also possible, of course, to energize an electrostrictive generator at its resonant frequency by some type of independent transducer connected to the ceramic member. For example, a conventional transformer could be used as a magnetostrictive transducer to mechanically stress a ceramic member. This function could be performed in addition to the operation as a normal electrical transformer. Such operation can be obtained by utilizing a low loss magnetostrictive material such as a ferrite which is tuned to the proper resonant frequency for the ceramic member. While a system of this type is fully operable, it has the disadvantage of requiring two different resonating members which must be maintained in corresponding resonance for proper drive of the ceramic member from the magnetostrictive transformer core. Furthermore, some inefficiency may be introduced by transmission losses at the interfaces of the core and ceramic members which may have different acoustic impedances. In the system wherein the ceramic member operates as a motor driver and

as a driven generator these problems are overcome and it is possible to obtain a maximum voltage step-up with greater efficiency and to experience no difficulty in matching materials and maintaining the match during utilization of the device.

In the foregoing there has been described an electromechanical device to produce a high voltage waveform upon energization from a relatively low potential resonating drive signal. It can be seen that the device is of relatively simple and sturdy construction and it may be formed in a manner to remain in reliable service over a long period of time. While the device is an impedance transformer, just as the conventional inductive transformer, the one described is basically an electromechanical transducer which is highly efficient and has particular application for energizing the screen of a cathode ray tube since suitable periodic energizing signals are available in a cathode ray tube system for scanning of the cathode ray beam. By utilizing the described design it is possible to produce voltage step-up greatly in excess of 100 times while still maintaining very desirable efficiency in voltage transforming of the type required in television and other like applications. The invention further provides an improved way of prestressing the electromechanical transducer to the point where it is capable of withstanding high driving voltages without damage.

I claim:

1. A piezoelectric transducer for transforming alternating current voltage of a given frequency applied thereto, including in combination, an annular member formed of piezoelectric material as a closed hoop and having a diameter to be resonant at the given frequency in the hoop mode of vibration, said member having an axial dimension which is at least as great as the radial dimension thereof, first and second electrode means positioned on said member for applying a voltage field thereto and extending around said hoop-shaped member more than one-half the circumference thereof, the portion of said member between said first and second electrode means being polarized in the direction of the applied voltage field to be driven in resonant vibration according to applied voltage of the given frequency, and third electrode means positioned on said member symmetrical with respect to said first and second electrode means, the portion of said member between said first and second electrode means and said third electrode means being polarized in the direction of the circumference of said member such that said third electrode means will conduct electrical signals produced by the piezoelectric effect, the axial dimension and radial dimension of said closed hoop providing substantially uniform mechanical stress throughout the body thereof, whereby hoop mode vibration of said member produces a transformed output voltage at said third electrode means with minimized input and output impedances.

2. A piezoelectric transformer for transforming alternating current voltage of a given frequency applied thereto, including in combination, an annular piezoelectric member in the form of a closed hoop having a diameter to be resonant substantially at the given frequency in the hoop mode of vibration, said member having a generally rectangular cross-sectional area of which the axial dimension is at least as great as the radial dimension, a first electrode and a second electrode, each of said electrodes having electrically connected first and second plate portions, said first and second plate portions of each of said electrodes being positioned on the inside and outside surfaces respectively of said member, said second plate portions of each of said electrodes including conductors thereon for applying the input voltage across said first and second electrodes to strain said member at the radial dimension thereof according to the piezoelectric effect, said member being vibrated in the hoop mode due to Poisson coupling, and a third electrode positioned on said member symmetrical with respect to said first and second electrodes for conducting therefrom an output voltage produced by the piezoelectric effect, the axial dimension and radial dimension of said closed hoop providing substantially uniform mechanical stress throughout the body thereof, whereby hoop mode vibration of said member produces a transformed output voltage at said third electrode with minimized input and output impedances.

3. A transducer device for producing mechanical vibrations from electrical signals of a given frequency applied thereto, including in combination, an annular member formed of ceramic material and having dimensions to be resonant at the given frequency in the hoop mode of vibration, said member having a rectangular cross-section, electrode means on said member positioned to strain said member along the circumference thereof to induce said member to vibrate in the hoop mode upon application of electrical signals of the given frequency to said electrode means, and glass filament wound about the outer diameter of said member and prestressing said member into compression along the circumference thereof, whereby the capacity of said member to withstand tensile stress about the circumference thereof is increased to permit increased driving voltages.

4. A piezoelectric transformer for transforming alternating current voltage of a given frequency applied thereto, including in combination, an annular member formed of ceramic material and having dimensions to be resonant at the given frequency in the hoop mode of vibration, said member having a rectangular cross-section and being of generally tubular configuration, first and second electrodes positioned on said member for driving the same according to applied voltage of the given frequency, a third electrode positioned on said member to conduct therefrom electrical signals produced by the piezoelectric effect, and glass filament wound about the outer diameter of said member and prestressing said member into compression along the circumference thereof, whereby the capacity of said member to withstand tensile stress about the circumference thereof is increased to permit increased driving voltage.

5. A piezoelectric transformer for transforming alternating current voltage of a given frequency applied thereto, including in combination, an annular member formed of ceramic material and having dimensions to be resonant at the given frequency in the hoop mode of vibration, said member having a rectangular cross-section and having an axial dimension which is at least as great as the radial dimension thereof, first and second electrodes positioned on said member for driving the same according to applied voltage of the given frequency, a third electrode positioned on said member to conduct therefrom electrical signals produced by the piezoelectric effect, first, second and third resilient conductors attached respectively to said first, second and third electrodes for providing a conductive connection thereto, said conductors being of sufficient rigidity to support said member in an operative position, and glass filament wound about the outer diameter of said member and enclosing said conductive strips, said glass filament prestressing said member into compression along the circumference thereof, whereby the capacity of said member to withstand tensile stress about the circumference thereof is increased to permit increased driving voltages.

6. A transducer device for producing mechanical vibrations from electrical signals of a given frequency applied thereto, including in combination, a member comprised substantially of field strictive material and having dimensions to be resonant at the given frequency in vibration in a predetermined direction, energizable means on said member positioned to strain said member in the predetermined direction to induce said member to vibrate upon application of electrical signals of the given frequency to said energizable means, and glass filament

wound about said member and prestressing said member into compression along the predetermined direction, said glass filament having substantially the same properties of thermal expansion as said member, whereby the capacity of said member to withstand tensile stress in the direction of vibration is increased to permit increased driving voltages.

7. A transformer comprising an annular member formed of piezoelectric ceramic material and having a mean diameter selected to be resonant at a given frequency in the hoop mode of vibration, said member having a rectangular cross-section with an axial dimension which is substantially greater than the radial dimension thereof, input electrodes comprising electric conductors positioned respectively on the inside and outside circumference of said member and extending partially about the circumference of said member to define a driving area thereof across which an electric field is applied, an output electrode disposed on said member diametrically opposite said input electrodes and spaced therefrom to define driven areas of said member between said input and output electrodes thereof, means for applying input signals to said input electrodes at substantially the resonant frequency of said member, means for deriving an output signal from said output electrode, and electrical insulation disposed about the outer circumference of said member and applying compression thereto to maintain said member below the tensile fracture point thereof throughout the range of input signals applied to said input electrodes.

8. A transducer device for producing mechanical vibrations from electrical signals of a given frequency applied thereto, including in combination, a member comprised substantially of field strict material and having dimensions to be resonant at the given frequency in vibration in a predetermined direction, energizable means on said member positioned to strain said member in the predetermined direction to induce said member to vibrate upon application of electrical signals of the given frequency to said energizable means, and insulation material disposed about said member and pre-stressing said member into compression along the predetermined direction, said insulation material having substantially the same properties of thermal expansion as said member, whereby the capacity of said member to withstand tensile stress in the direction of vibration is increased to permit increased driving voltages.

9. A transformer for transforming alternating current voltage of a given frequency applied thereto, including in combination, an annular member formed of material responsive to electric field stress thereof to produce an electric potential, said member being formed in the shape of a closed hoop and having a mean diameter to be resonant substantially at the given frequency in the hoop mode of vibration, said annular member having a cross-sectional area such that the axial dimension thereof exceeds the radial thickness thereof and the axial dimension thereof being less than one-fifth of the means diameter of said annular member, first and second electrodes positioned on arcuate portions of said member to embrace a driving region of said transformer, said driving region being direct current polarized and responding to applied voltage of the given frequency, and a further electrode positioned on said member diametrically opposite said first and second electrodes to define driven sections of said member between said further electrode and said first and second electrodes, said driven sections of said member being polarized along the circumference thereof, whereby hoop mode vibration of said member provides substantially uniform mechanical stress thereof for producing a transformed output voltage at said further electrode with minimized input and output impedances.

10. A transformer device, including in combination, an annular member formed of material responsive to the stress of an electric field thereon to produce an electric potential, said annular member being formed in the shape of a closed hoop and having a mean diameter to establish hoop mode vibration therein at a given frequency, said annular member having a cross-sectional area such that the axial dimension thereof exceeds the radial thickness thereof, first and second electrodes positioned on arcuate portions of said member to embrace a driving region of said transformer, said driving region being direct current polarized between said first and second electrodes, and a further electrode positioned on said member diametrically opposite said first and second electrodes to define driven sections of said member between said further electrode and said first and second electrodes, said driven sections of said member being direct current polarized along the circumference thereof, the axial dimension and radial thickness of said closed hoop providing substantially uniform mechanical stress throughout the body thereof, whereby hoop mode vibration of said member produces a transformed output voltage at said further electrode with minimized input and output impedances.

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