

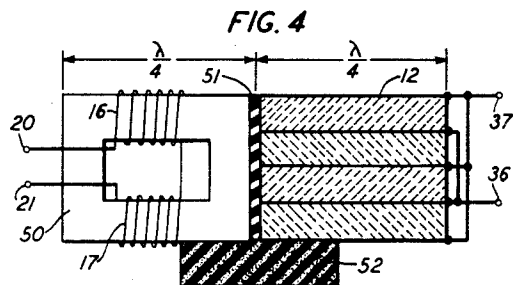
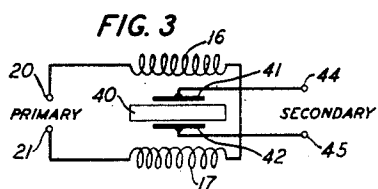
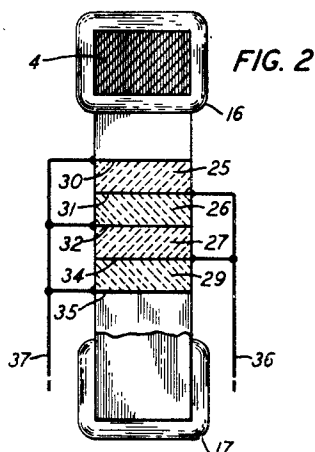
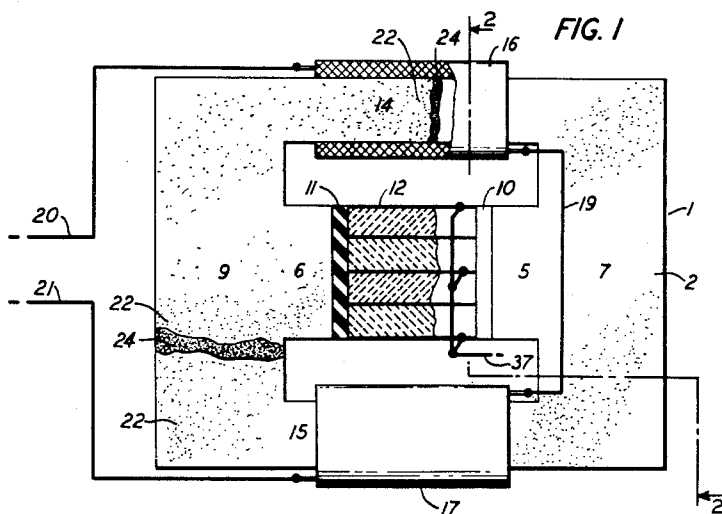
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STRESS-COUPLED CORE AND CRYSTAL TRANSFORMER

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STRESS-COUPLED CORE AND CRYSTAL TRANSFORMER

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This invention relates to transformers, and particularly to a stress-coupled core and crystal transformer of high-impedance ratio.

The invention contemplates the use in combination of the piezoelectric effect in crystals and the magnetostrictive effect in a properly constructed core. In accordance with the embodiments to be disclosed herein, current applied through a primary winding causes changes in the core dimensions, and hence in the mechanical forces applied to the crystal, which may be mounted under initial compression between elements of the transformer core, or else secured to one end thereof and the assembly freely supported on a resilient base. In the latter case the inertia of the crystal itself is utilized to convert the magnetostrictive changes into varying pressures thereagainst. These pressures produce varying potentials at the crystal terminals which may be high relative to those applied to the primary winding. Conversely, potentials applied across the crystal terminals will produce mechanical stresses against the core elements, which in turn will cause a change in the flux threading the primary winding, so that potentials which may be low relative to those across the crystal will be set up in the primary winding.

The invention has been illustrated schematically in the drawings, in which:

Fig. 1 is an elevational view partly broken away to show the construction of the core, primary winding, and crystal elements;

Fig. 2 is a view, partly in section, taken as indicated by line 2—2 of Fig. 1;

Fig. 3 is a circuit diagram illustrating in elementary form the electrical connections of the component parts of the transformer; and

Fig. 4 is a partially sectional representation of another preferred embodiment of the invention.

It is to be understood that the embodiments of Figs. 1—4 are exemplary only of the principles of the invention, and that other forms may be utilized incorporating structural equivalents within the scope of the appended claims.

The transformer, indicated generally as 1 in Fig. 1, is shown as having a rectangular core 2 formed of a plurality of laminations 4, and having a pair of opposed legs 5 and 6 extending toward each other from the core end portions 7 and 9, respectively. The core is formed of special alloys and properly heat treated, as is well understood in the art, to provide for the greatest magnetostrictive changes. A plate 10 of rigid insulating material is secured to the leg 5, and a similar plate 11 is fixed to the opposite leg 6. The plates

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10 and 11 may be formed of a phenol resin condensation product such as that known commercially as Bakelite, or of any equivalent material. These plates, shown to an exaggerated scale in the drawings for ease of illustration, are relatively thin and act to insulate the transformer core from the crystal element, which is shown as a crystal block condenser 12. The plates may be of sheet material only a few thousandths of an inch thick, or even a film of Bakelite cement, depending on the potentials involved.

The crystal block condenser 12 is inserted between legs 5 and 6 under an initial compression. The longer legs 14 and 15 of the core 2 have disposed thereon primary winding sections 16 and 17, respectively, which are connected series aiding by a lead 19 and have output leads 20 and 21. The sections 16 and 17 may be wound directly on the core to secure maximum flux.

The core 2 is built up of thin laminations 4, which may be of the order of .004 inch thick, formed of magnetostrictive material such as nickel or "Permendur," an alloy composed of substantially 50 per cent iron and 50 per cent cobalt. In order to secure the maximum magnetostrictive effect, the core laminations are insulated by annealing them in air to produce an oxide coating 22 on each, cemented together by a very thin layer of Bakelite or other equivalent cement 24, and cured with the laminations tightly clamped together. This type of construction restricts the mechanical damping loss to a very low value. It also tends to insure that the strains in the metal will be purely tensile or compressive. This prevents the reduction in magnetostrictive response which would be experienced if flexure were permitted. The coils are then wound on the core, cemented to it by vacuum impregnation with Bakelite cement, and cured under heat.

The crystal block condenser 12 is made up of a number of quartz, Rochelle salt, ADP or other piezoelectric crystals 25, 26, 27, 28 and 29. In a particular embodiment, the dimensions are of the order of one-half inch square by one-eighth inch thick. If quartz crystals are used, they should be X-cut; Rochelle salt crystals should be 45 degrees X- or Y-cut; ADP crystals should be 45 degrees Z-cut, and suitable cuts should be used for other kinds of piezoelectric crystals. All the crystals should be polarized in the same direction, and all in longitudinal modes. The crystals are separated by gold foil electrodes 30, 31, 32, 34 and 35 which are brought out alternately on opposite sides of the block to provide parallel connections to the individual blocks through leads

36 and 37. As an alternative to the assembly of the crystal elements under initial compression in the core, the insulating plates 10 and 11 may be firmly bonded both to the core legs 5 and 6 and to the crystal block 12.

A simplified schematic circuit for the transformer is shown in Fig. 3, in which primary windings 16 and 17 are shown connected series aiding between the primary terminals 20 and 21. The crystal condenser is represented by a single crystal 40, to which are attached electrodes 41 and 42 connected to the secondary terminals 44 and 45.

In Fig. 4 is illustrated another embodiment, in which the crystal block condenser is mounted outside the core, rather than inside, and between elements of, the core. In this form, the inertia of the crystal provides the mechanical resistance to the magnetostrictive changes in core size necessary to develop the potentials across the crystal condenser. The entire assembly is mounted on a resilient support permitting free vibration.

The rectangular core 50 has terminally secured thereto by suitable means, such as Bakelite cement, an insulating plate 51. Plate 51 may be, as in the embodiment of Fig. 1, reduced in thickness to a thin sheet or film of Bakelite. The function may in some cases be performed by the layer of Bakelite cement which secures the crystal block condenser 12 to the core 50. The dimensions of the crystal condenser 12 and the core 50 should be so chosen that each is equal in length to

$$\frac{\lambda}{4}$$

where λ is the wavelength at the desired resonant frequency. The composite structure then becomes a half wave vibrator and may be used as an oscillator at the frequency of mechanical resonance. For a particular embodiment in which the core measures approximately two inches by one and one-half inches, resonance is obtained at frequencies of the order of 20 kilocycles. Lower resonant frequencies may be obtained by changing the size and shape of the core. The device may be driven either on the high or low impedance side when used as an oscillator. The primary windings 16 and 17 are connected to terminals 20 and 21, while the secondary terminals 36 and 37 are provided for connection to the crystal block condenser 12, as in the showing of Figs. 1 and 2. The entire assembly is mounted on a resilient support, shown as a sponge rubber block 52, which permits the crystal and core to vibrate freely without exerting an appreciable damping effect.

In the device as described, good coupling is obtained with relatively low mechanical loss. Eddy current and hysteresis loss are comparable with that experienced in a transformer of the usual type. Eddy current loss is anticipated to provide the major restriction on efficiency, and may impose an upper limit on the frequency range within which the transformer is usable. There is, however, an inherently high impedance ratio, together with advantages in size and ease of manufacture not found in existing transformers of the conventional type, due to the elimination of the high voltage winding and the attendant insulation problems.

For satisfactory operation of magnetostrictive devices there must be a steady state biasing flux,

which is facilitated by the use of material such as nickel, Permendur, or "vanadium Permendur," an alloy composed of substantially 49 per cent iron, 49 per cent cobalt, and 2 per cent vanadium, heat treated to operate on remanence, so that no direct current biasing power is required. In some cases, however, it may be preferable to add direct current biasing power through conventional means, not shown in the figures. The biasing current may, for example, be applied through the primary or through a separate biasing winding.

In planning a transformer of this type for specific applications the impedance ratio may be varied widely in accordance with the choice of several factors in the design. The input impedance will vary with the core dimensions, the number of turns, the core material, and its steady state magnetization. The output impedance will vary with the crystal material used, with the cut of the individual crystals and with the block dimensions, particularly the thickness and number of blocks used.

With these factors constant, the voltage ratio may be shown to be inversely proportional to the frequency, and the impedance ratio to be inversely proportional to the square of the frequency. Hence many of the important uses of the invention utilizing the inherently high voltage and impedance ratios are anticipated to be found in the low frequency range, and in direct current applications. Exemplary of the former are amplifier input transformers, and of the latter, the firing of cold cathode tubes, as in electronic switching arrangements triggered by low potentials from telephonic circuits. In such direct current applications, a solid core may be used instead of the laminated construction, since eddy current loss is there of minor importance.

It will be seen from the foregoing description that a simple, compact, and easily constructed transformer is here presented having considerable advantages for certain special applications where high impedance and voltage ratios are desired.

What is claimed is:

1. A transformer comprising a hollow, substantially rectangular, magnetostrictive core having a pair of legs extending toward one another from opposite sides of said core and terminating in spaced opposed faces, means comprising a winding on said core for exciting it to vary the spacing between said faces, a piezoelectric crystal between said faces and mechanically connected thereto, whereby said crystal is stressed in accordance with the variations in said spacing, and electrical connections to said crystal.

2. A transformer comprising an apertured core of magnetostrictive material forming a closed magnetic circuit, piezoelectric crystal means, means mounting said piezoelectric crystal means under stress between opposite portions of said core and arranged for the mutual transmission of stress between said core and said crystal means, a winding on said core, and electrical connection means to said crystal and said winding.

3. A transformer comprising a closed loop of magnetostrictive material, a winding disposed about said loop, a piezoelectric crystal, means mounting said crystal under compression between opposite sides of said loop for positive transmission of stresses between said loop and said crystal, whereby transformation may be attained in either direction between said winding

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and said crystal, and lead means for electrical connection to said winding and said crystal.

4. A transformer providing transformation in either direction between a high voltage side and a low voltage side comprising an apertured core of magnetostrictive material forming a closed magnetic path, a winding positioned around said core and defining the low voltage side, a piezoelectric crystal defining the high voltage side, and means mounting said crystal under stress in said aperture between opposite sides of said core whereby dimensional changes in said crystal and said core are interrelated to voltage changes on said high and low voltage sides.

5. A high impedance ratio transformer comprising an apertured magnetostrictive core forming a closed magnetic path, a piezoelectric crystal, means mounting said crystal under pressure within said aperture between opposite portions of said core and arranged for the positive mutual transmission of stress therebetween, a winding disposed about said core, and electrical connections to said winding and said crystal.

6. A transformer comprising a primary and a secondary side, a crystal block condenser defining said primary, means for applying varying

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high potentials to said crystal block condenser, a closed loop of magnetostrictive material defining a closed magnetic path, means mounting said crystal block condenser within said loop for the transmission of forces generated by said crystal block condenser to said loop, a winding disposed about said loop defining said secondary, said winding being arranged to be linked by the magnetic fields varying with mechanical stresses set up in said loop in response to said varying high potentials, and output lead means connected to said winding.

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