

XR

1,899,163

U.S. PAT. OFF.

49

X89577

2

Feb. 28, 1933.

W. A. MARRISON

1,899,163

PIEZO ELECTRIC CRYSTAL

Original Filed Dec. 19, 1928

FIG. 1

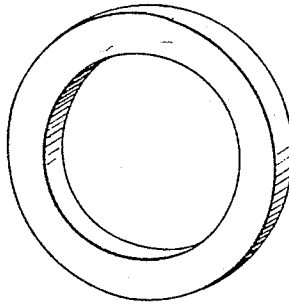


FIG. 2

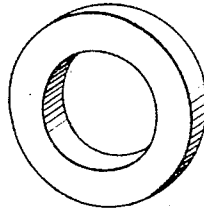
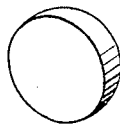


FIG. 3



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

327
Patented Feb. 28, 1933

1,899,163

UNITED STATES PATENT OFFICE

WARREN A. MARRISON, OF MAPLEWOOD, NEW JERSEY, ASSIGNOR TO BELL TELEPHONE LABORATORIES, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK

PIEZO-ELECTRIC CRYSTAL

Original application filed December 19, 1928, Serial No. 327,017. Divided and this application filed November 1, 1930. Serial No. 492,668.

This application is a division of my co-pending application Serial No. 327,017, filed December 19, 1928.

This invention relates to piezo-electric crystals and particularly to crystals having a small temperature coefficient of frequency, and methods of cutting such crystals.

The advantages of utilizing the piezo-electric effect of substances possessing such properties have been known for some time. The uses for a constant frequency control and especially the need of such control within more rigid limits, are constantly increasing. Such uses include the control of broadcasting stations on their assigned wave lengths, whether locally or by transmission of a wave from a central control point, and control of the frequency of local oscillations in a heterodyne receiver. Frequency control means are also useful in connection with sending and receiving sets of picture transmission and television in order to avoid the necessity of a synchronization channel and similarly in systems of carrier wave telephony and telegraphy, and are also important elements of laboratory reference standards.

An object of this invention is to provide a piezo-electric resonator whose resonant frequency of vibration does not change with variations in temperature.

A feature of this invention is a disc shaped piezo-electric resonator having a zero temperature coefficient of frequency.

The drawing shows perspective views of a series of piezo-electric resonators of the invention, formed from a single crystal, the resonator of Fig. 2 having been cut from that of Fig. 1, and the resonator of Fig. 3 having been cut from that of Fig. 2.

The stiffness, and the temperature coefficient of stiffness, of quartz crystals, are different along different axes. The effective stiffness along any given axis is the sum of at least two effects, one being the usual mechanical stiffness, such as exists in ordinary iso-

tropic substances, and another being due to the reaction of the electric field set up within and around a piece of mechanically strained piezo-electrically active material.

When an elastic body is deformed in a given direction by a force applied in that direction, there is a corresponding, but smaller deformation in the perpendicular direction, as well as a change in volume. When a quartz resonator is set in resonant vibration, there is a large periodic change of length in one direction, called the direction of vibration, and a vibration of the same frequency in a transverse direction. The transverse vibration is due partly to the mechanical tendency of the material to maintain constant volume, partly to the mechanical coupling between the two modes of vibration, and partly to the electrical coupling between the electrodes and the resonator perpendicular to the principal direction of vibration. Thus the effective stiffness which determines the resonant frequency of a resonator in a given mode is a complex quantity dependent on the relative dimensions along different resonator axes, the orientation with respect to the original crystal axes, the size, number, spacing, and arrangement of electrodes about the resonator, the voltage impressed upon the resonator in various directions in relation to the dimensions and orientation of the resonator, and the impedance of the electrical circuit to which the resonator is coupled.

Because of the various factors above mentioned which determine the stiffness characteristics for given modes of vibration, there results a similar complexity as to the temperature coefficient of stiffness for the corresponding modes of vibration, hence it tends to result that the temperature coefficient of stiffness, and therefore the frequency, of a resonator in a given mode may be varied over a considerable range by suitably proportioning the resonator.

The inherent temperature coefficient of

frequency is different along an electrical axis of a crystal from that in a perpendicular direction along a crystallographic axis. (A discussion of the axes of a quartz crystal may be found in a paper on the "Uses and Possibilities of Piezo-Electric Crystals," by August Hund, in the Journal of the Institute of Radio Engineers, for August, 1926, commencing on page 447.)

If a disc shaped plate is cut from a quartz crystal in the plane of an electrical axis and the optical axis and having a sufficiently large cross-sectional area in proportion to its thickness, as in Fig. 1 without the center removed, it will be found to have a positive temperature coefficient of frequency. If an outer rim is removed and another measurement is taken of the resulting disc, having greater thickness in proportion to its cross-sectional area, as Fig. 2 without the center removed, it will be found to have a smaller positive temperature coefficient of frequency. If another rim is removed from the smaller plate, the temperature coefficient of frequency of the resulting disc, as in Fig. 3 will again be found to have decreased. It will continue to decrease passing through zero to negative values. These measurements are, of course, all made at the same temperature so the crystal will vibrate at the desired frequency at a desired temperature.

To cut a disc shaped resonator with a zero temperature coefficient of frequency, a disc is first cut from a crystal parallel to an electrical axis and the optical axis, ground to the thickness corresponding to a frequency slightly lower than the frequency desired, and its temperature coefficient adjusted by grinding the periphery until the point has been reached where it has a slightly negative temperature coefficient. A final adjustment of frequency and temperature coefficient is then made by grinding to the proper thickness.

It is necessary to make the adjustment in three steps instead of two because the first adjustment of frequency has an effect on the temperature coefficient, and the adjustment of the temperature coefficient has a very slight effect on the frequency. If the exact dimensions are known for a desired frequency with a zero temperature coefficient at a given orientation of the resonator with respect to its crystal axes, it may be cut directly to these dimensions in two steps.

Advantages of resonators which have a zero temperature coefficient of frequency are that the necessity for temperature controlling means is avoided, and furthermore as the resonator heats up due to load applied to it, the frequency does not change due to either the initial heating or to variations in load.

What is claimed is:

1. A quartz crystal piezo-electric resonator disc, the plane of which is parallel to the

optical and one of the electrical axes of the crystal and having its diameter and thickness so related that its temperature coefficient of frequency is zero at a specified temperature.

2. A disc shaped resonator having its plane determined by the optic and one of the electrical axes and having its thickness and diameter so related that its temperature coefficient of frequency is substantially zero.

In witness whereof, I hereunto subscribe my name this 31st day of October, 1930.

WARREN A. MARRISON.

