Exercise 1

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1 Objective

The most commonly used oscillators are quartz crystal oscillators. What is their operating principle? What are their operating frequency ranges? What are typical quality factors?

2 Quartz Properties

Quartz is a crystalline material composed of molecules made of silicon and oxygen. The structure of quartz allows it to operate under the piezo-electric effect; as a result, quartz is commonly used as a material in various devices such as telephones, laptops, etc.

The principle it works under allows it to vibrate at frequencies ranging from a few kHz to hundreds of MHz. The size, shape, and orientation of the crystal can change the required voltage or force needed to achieve a certain frequency. These three factors can also change how the crystal vibrates.

2.1 Atomic Structure

A single quartz molecule is made of one silicon atom and four oxygen atoms, all of which bond to the silicon atom. Silicon has a positive charge, while the oxygen atoms are negatively charged, so four dipoles are formed in its tetrahedral structure. When undisturbed, the dipoles are oriented to cancel each other out, creating a zero net charge through the molecule. When a force is applied to it, the dipoles shift in a way that the top vertex of the structure is positive and the rest are negative.

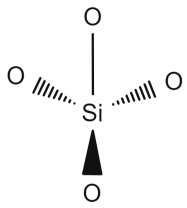

Figure 1: Schematic structure of quartz tetrahedron molecule

A quartz crystal has a crystalline atomic structure where each molecule are conjoined together at the oxygen atoms. In the figure below, each oxygen atom is bonded to two silicon atoms, each of which is bonded to three oxygen atoms, and so on.

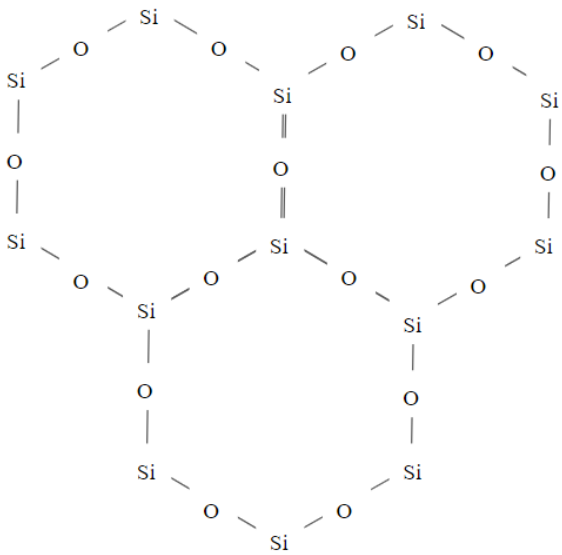

Figure 2: Schematic structure of quartz crystal

2.2 Piezo-electricity

The piezo-electric effect is a phenomenon discovered by Pierre and Jacques Currie, brothers and physicists from the late 1800s. They discovered that some materials produce a voltage when physical force is applied to them, and those materials vibrate when current is run through them. Under this principle, quartz can have a wide variety of applications. One application is to install quartz into public areas or roads to absorb the mechanical energy generated by people or cars on the road.

It is practical to make cuts of quartz so that it has two parallel faces. Then a force is applied to it so that each molecule in the quartz slab will shift its dipoles in order for both faces to have equal and opposite charges. The opposite charges create a voltage, like a battery or a capacitor, so when it is connected to a circuit current is generated.

Works Cited

1. Cady, W. G. (1921). “The piezoelectric resonator”. Physical Review. 17: 531533.

2. C. Woodford. (2018). Piezoelectricity - How does it work?. https://www.explainthatstuff.com/piezoelectricity.html.

3. C. Lu and A. W. Czanderna, eds. Applications of piezoelectric quartz crystal microbalances, Vol. 7, Elservier (2012).