Crystal Filter

■ Terminology

Main terms used for crystal filters are described as follows:

Nominal Frequency : The nominal value of the center frequency in Figure 1 is normally used as the standard frequency of the related standards.

Passband Width : Frequency intervals when it is guaranteed that the value of relative attenuation is the same as, or less than, that of the specified attenuation.

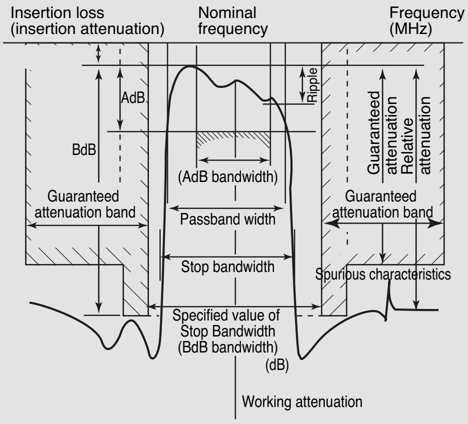
Ripple : When the maximal value of attenuation exists in the passband, the maximal value among the differences of the maximal attenuation and the minimal attenuation is called a ripple.

Insertion Loss (Insertion Attenuation) : The electric power supplied for load impedance and is the ratio of before a crystal filter is inserted and after the filter has been inserted. This is generally expressed in decibels. Insertion loss is treated as the reference level of attenuation.

Stop Bandwidth : The frequency width when it is guaranteed that the value of relative attenuation is the same as or more than that of the specified attenuation.

Guaranteed Attenuation and Guaranteed Attenuation Band : Relative attenuation and its frequency band guaranteed in the attenuation band.

Terminating Impedance : Defined as source impedance or load impedance viewed from the filter side, and it is generally expressed by resistance and shunt capacitance.



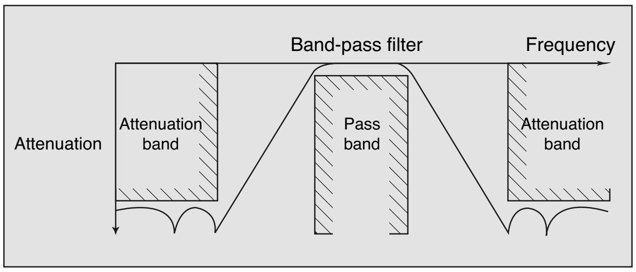
(Note) AdB: Attenuation that specifies passband width
BdB: Attenuation that specifies stop bandwidth

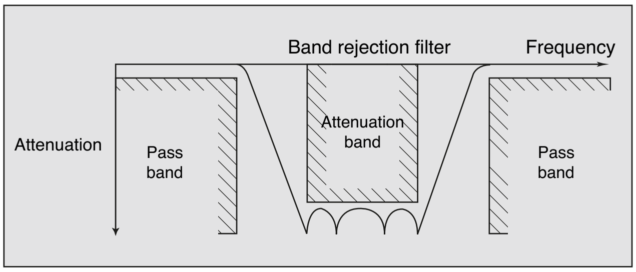
Figure 1 Terminology

Balanced Type and Unbalanced Type : The balanced type means that neither of a pair of terminals is connected to the case, and the unbalanced type means that one of a pair of terminals is connected to the case.

■ Explanation

Because of the properties of its resonator a crystal filter has the distinct advantage of being both a band-pass filter and a band rejection filter .





Described here are the general characteristics of the type of band-pass filter that is most widely used as a crystal filter.

Scope of Realization

A band-pass filter is roughly divided into two types according to its basic configuration.

One is a “narrowband filter” whose element section consists of a crystal resonator and a capacitor. This filter is designed so that its passband width is 0.005 to 0.6 % of the center frequency. The upper limit of the bandwidth is determined by the capacitance ratio of the crystal resonator (C_0/C_1), and the lower limit is determined mainly by the Q of the crystal resonator and the stability of the frequency.

When a coil and a capacitor are connected to a crystal resonator in series or in parallel in the element section in its configuration, the lower limit of the bandwidth is determined by the stability and the Q of the coil. The upper limit however, depends on the capacitance ratio, spurious characteristics, etc. of the crystal resonator, and it is determined by the stability of a coil, transformer, etc. used for a filter circuit and by Q.

Many **“intermediate band filters”** are manufactured for a part and intermediate range of the aforementioned narrowband, and a coil is needed to negate the capacitance of a crystal resonator and that of a circuit. The upper limit of the passband width is related to the capacitance ratio of the crystal resonator and the Q of the coil, and the lower limit is determined by the same factors that affect the conditions of the narrowband filter.

In Figure 2, the schematic manufacturing scope of band-pass crystal filters is indicated by the relationship between frequencies and passband width. However, strictly speaking, the scope of possibilities increases or decreases according to the requested conditions, such as attenuation curve, attenuation, ripple, dimensions, and price.

■ Explanation

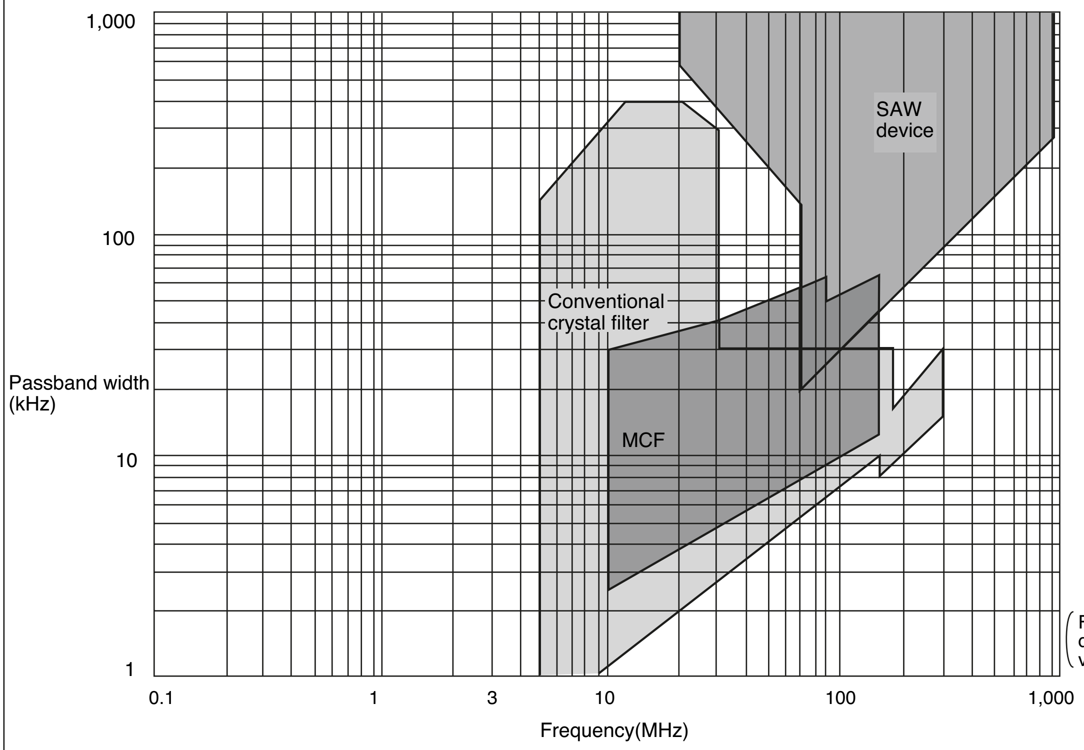


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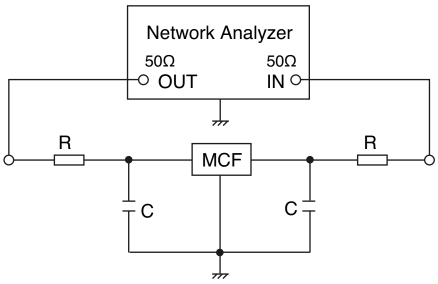
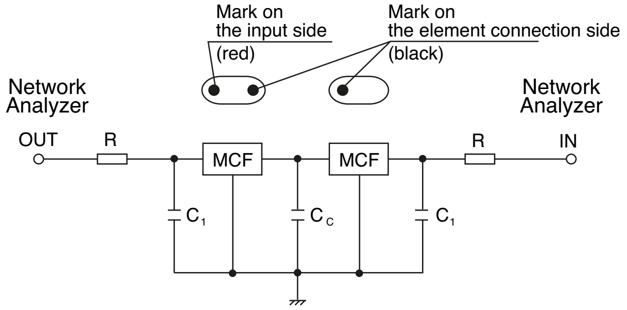
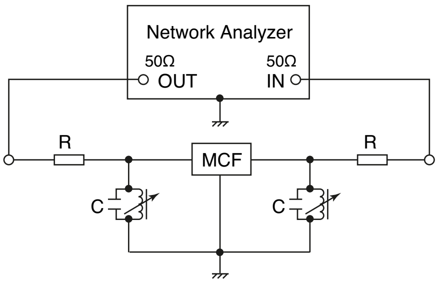
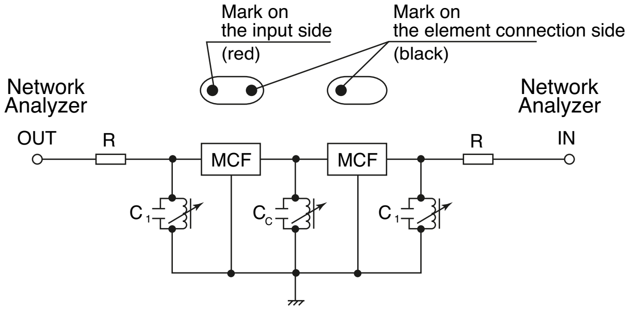
Figure 2 Schematic manufacturing scope of band-pass crystal filters

■ Measurement Circuit

The figures below show measurement circuits for measuring filter characteristics. There are two types of measurement circuits: capacitive and inductive. In the capacitive circuit, filter characteristics can be checked by attaching specified capacitance to the circuit. In the inductive circuit, an LC tuned circuit is needed to negate distributed capacitance or compensate for negative capacitance. In order to check filter characteristics, it is necessary for the LC tuned circuit to be adjusted and for the value of the circuit to be the same as a specified value.

	Measurement Circuit	Measurement Circuit (Two-element Pair Type)
Capacitive	 	
Inductive	 	

Explanation

Explanation of General Characteristics

Attenuation Curve

There are various attenuation curves, depending on the characteristic functions, position and degree of attenuation poles, etc. used for designing filters. As representative examples, Figures 3a and 3b show basic attenuation characteristics, both when it is assumed that the passband has Chebyshev (equal ripple) characteristics and when it is assumed that the passband has Butterworth (flat) characteristics with in both cases the attenuation pole having infinite characteristics. Here, Ω is normalized by 3dB-passband width and is obtained from the equation below. The attenuation characteristics become symmetrical when Ω is 0 (center frequency).

$\Omega = (f-f_0) / (BW/2)$

f_0 : Filter center frequency
f : Attenuation characteristics frequency
BW : 3dB-passband width

Phase Characteristics

Phase characteristics, similar to attenuation characteristics, differ, depending on characteristic functions, degree, etc. for designing filters. Figure 4 shows the phases of the aforementioned Chebyshev and Butterworth characteristics. Linear phase filters can be designed upon request.

However, the manufacturing scope is subject to more constraints than in Figure 2 (page 205).

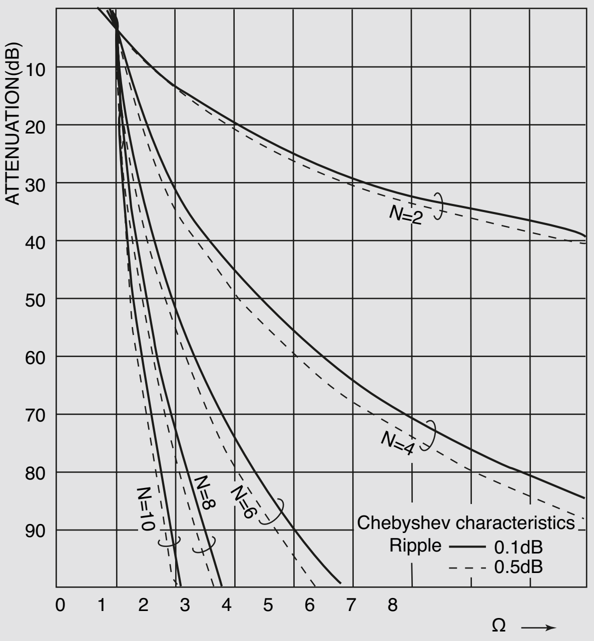


Figure 3a Attenuation characteristics (Chebyshev characteristics)

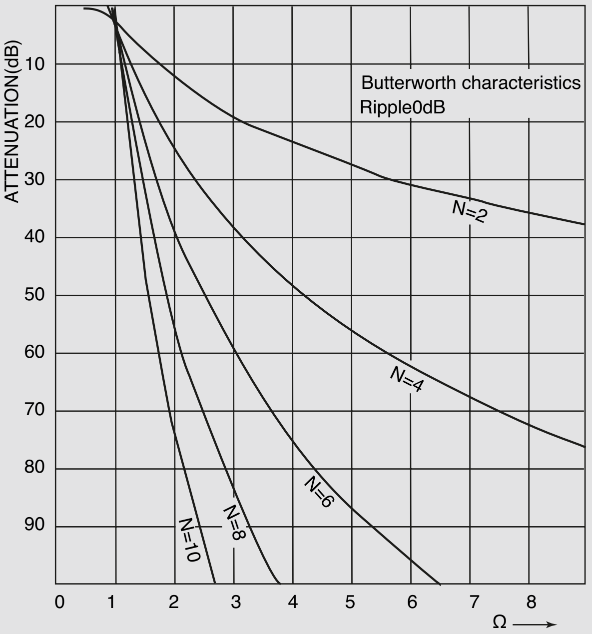


Figure 3b Attenuation characteristics (Butterworth characteristics)

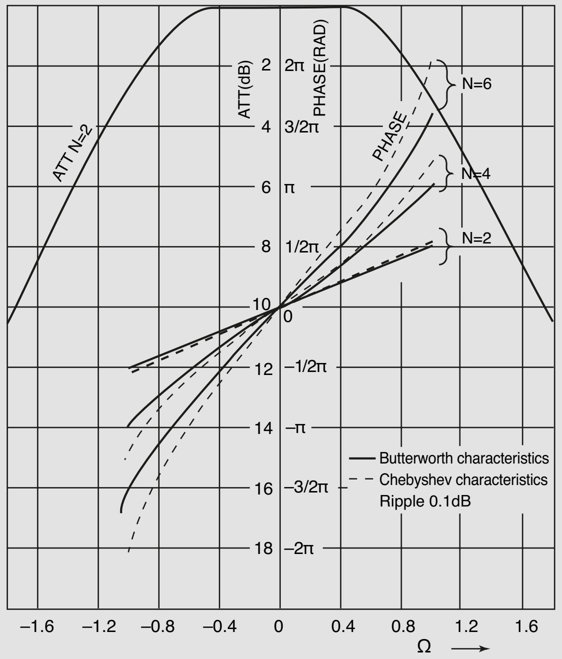


Figure 4 Phase characteristics