For more than two decades, ceramic filter technology has been instrumental in the proliferation of solid state electronics. A view of the future reveals that even greater expectations will be placed on piezoelectric material in the area of new applications and for more stringent performance criteria in current products. Traditionally, nearly all low and high-end AM and FM commercial radios use ceramic band-pass filters. However, applications are also found in cordless telephones, cellular systems, 2-way communications, and the television industry.

As a world leader in the development of piezo ceramic filter technology, Murata Electronics had been able to develop specialized ceramic materials which when combined with an advance filter design have resulted in a complete line of practical, inexpensive ceramic filters for entertainment and communications applications. In this catalog, the principle of ceramic filters, the design of representative test circuits and specifications concerning various models are described.

PIEZOELECTRIC THEORY AS APPLIED TO CERAMIC FILTERS

All ceramic filters derive their basic frequency selectivity from a mechanical vibration resulting from a piezoelectric effect. While a total theoretical analysis of piezoelectric technology as applied to ceramic filters is very complex, it can be shown as the equivalent circuit as illustrated in Fig. 426-1. This equivalent circuit represents a typical two-terminal filter, a device which forms the basic building block for more complex filters.

The resonant frequency of this device is calculated by the equation:

$$f_r = \frac{1}{2\pi\sqrt{L_1 C_1}}$$

The anti-resonant frequency is expressed as:

$$f_a = \frac{1}{2\pi\sqrt{L_1 \frac{C_1 C_0}{C_1 + C_0}}}$$

This filter exhibits the impedance shown in Fig. 426-2.

Two-terminal filters are typically used as emitter bypasses and they exhibit the frequency characteristics shown in Fig. 426-3.

Three-terminal ceramic filters can be used as inter-stage coupling devices as shown in Fig. 426-4. By using our filters in this manner, increased selectivity, improved band pass characteristics, reliability and stability can be obtained without increasing circuit complexity or parts count.

By cascading two or more filters as shown in Figs. 427-5 and 6, Murata can greatly enhance selectivity. By controlling the coefficient of electromechanical coupling between the filter elements, bandwidth can be "peaked" or "flattened." Typical 455kHz response curves are shown in Figs. 427-7 and 8.

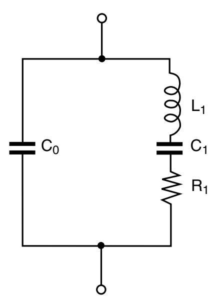

Fig. 426-1
Two-Terminal Type Equivalent Circuit

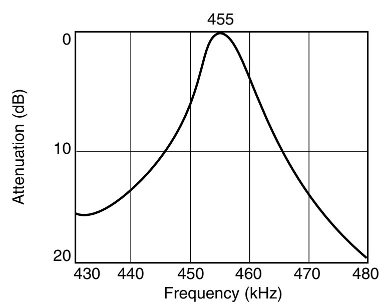

Fig. 426-3
Typical Attenuation Characteristics For A 455kHz (Two-Terminal) Ceramic Filter

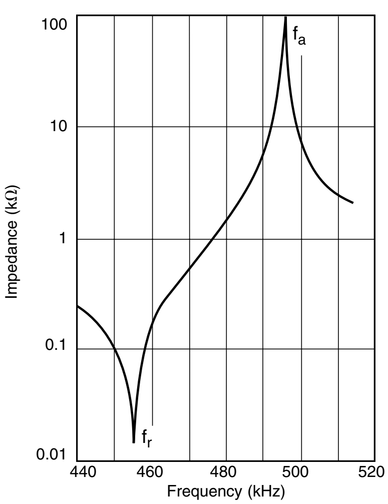

Fig. 426-2
Typical Impedance vs Frequency Response Curve For A Two-Terminal Device

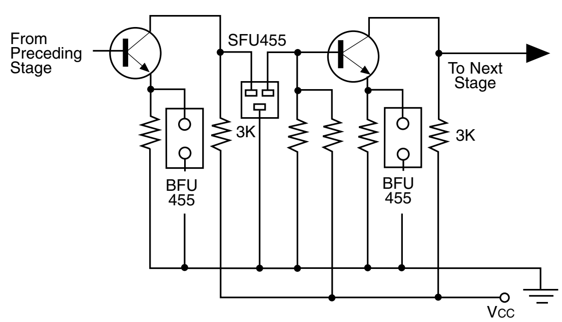

Fig. 426-4
Three-Terminal Filter Used As Inter-Stage Coupling Device

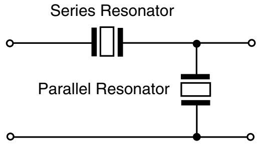

Fig. 427-5
Ladder Connection

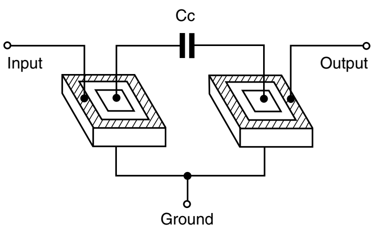

Fig. 427-6
Cascade Connection

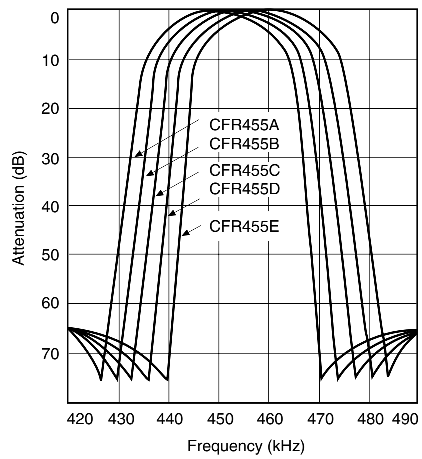

Fig. 427-7
Typical Response Curves For
CFR455 A-E Series Ceramic Filters

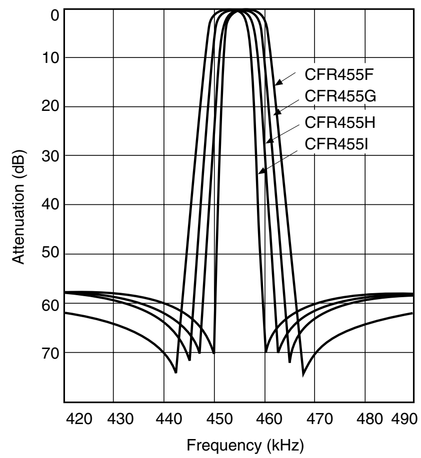

Fig. 427-8
Typical Response Curves For
CFR455 F-I Series Ceramic Filters

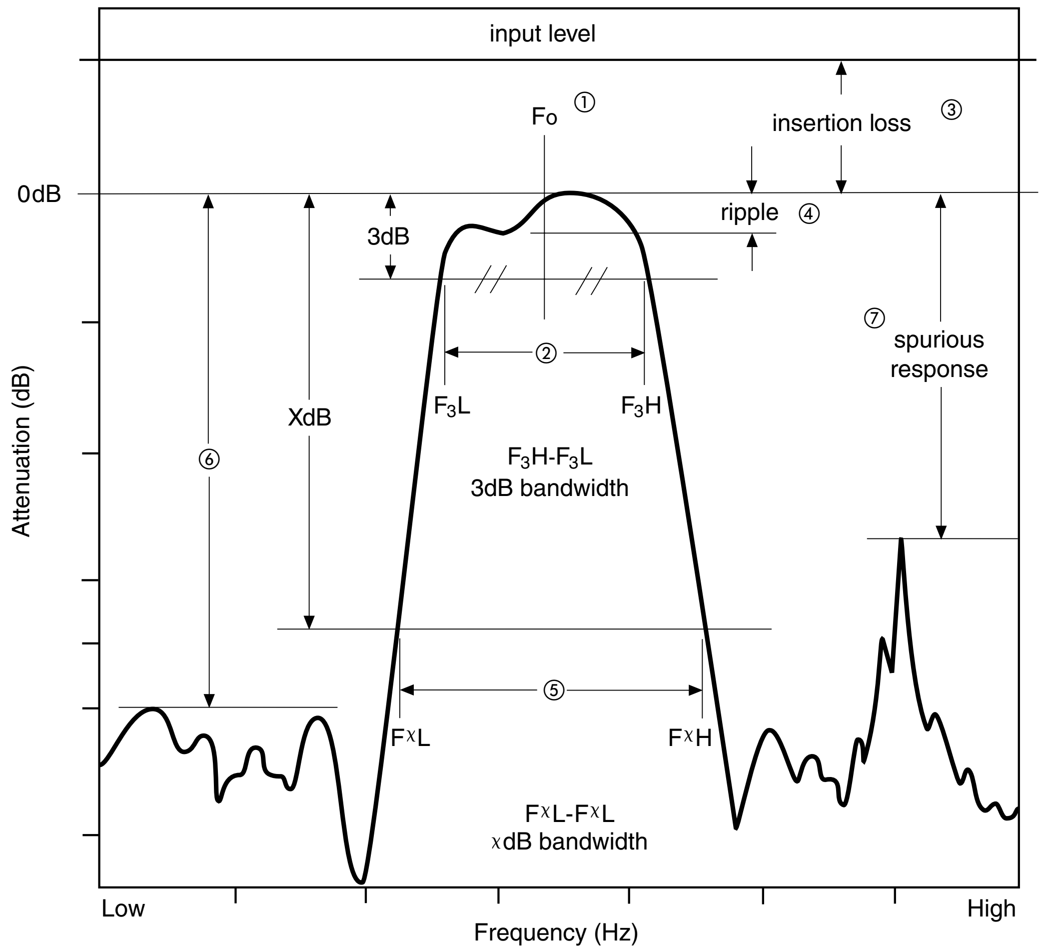

Fig. 427-9
Graphical Representation of Ceramic Filter Terminology

PIEZO FILTERS

CERAMIC FILTER TERMINOLOGY

Although the previous section has presented a concise discussion of piezoelectric theory as applied to ceramic filter technology, it is necessary that the respective terminology used in conjunction with ceramic filters be discussed before any further examination of ceramic filter technology is made.

Using Fig.427-9 as a typical model of a response curve for a ceramic filter, it can be seen that there are a number of relevant factors to be considered in specifying ceramic filters. These include: center frequency, pass-bandwidth, insertion loss, ripple, attenuation bandwidth, stopband attenuation, spurious response and selectivity. Although not all of these factors will apply to each filter design, these are the key specifications to consider with most filters. From the symbol key shown in Table 428-1 below, a thorough understanding of this basic terminology should be possible.

IMPEDANCE MATCHING

As it is imperative to properly match the impedances whenever any circuit is connected to another circuit, any component to another component, or any circuit to another component, it is also important that this be taken into account in using ceramic filters. Without proper impedance matching, the operational characteristics of the ceramic filters cannot be met.

Fig. 429-12 illustrates a typical example of this requirement.

This example shows the changes produced in the frequency characteristics of the SFZ455A ceramic filter when the resistance values are altered. For instance, if the input/output impedances R_1 and R_2 are connected to lower values than those specified, the insertion loss increases, the center frequency shifts toward the low side and the ripple increases.

TABLE 432-1 – CERAMIC FILTER TERMINOLOGY CHART

Numbers In Fig. 427-9	Terminology	Symbol	Unit	Explanation of Term
1	Center Frequency	f_o	Hz	The frequency in the center of the pass-bandwidth. However, the center frequency for some products is expressed as the point where the loss is at its lowest point.
2	Pass-bandwidth (3dB Bandwidth)	(3dB) B.W.	Hz	Signifies a difference between the two frequencies where the attenuation becomes 3dB from the level of the minimum loss point.
3	Insertion Loss	I.L.	dB	Expressed as the input/output ratio at the point of minimum loss. (The insertion loss for some products is expressed as the input/output ratio at the center frequency.) Insertion loss = 20 LOG (V_2/V_1) in dB.
4	Ripple	—	dB	If there are peaks and valleys in the pass-bandwidth, the ripple expresses the difference between the maximum peak and the minimum valley.
5	Attenuation Bandwidth (dB Bandwidth)	20 (dB) (B.W.)	Hz	The bandwidth at a specified level of attenuation. Attenuation may be expressed as the ratio of the input signal strength to the output signal strength in decibels.
6	Stopband Attenuation	—	dB	The level of signal strength at a specified frequency outside of the passband.
7	Spurious Response	SR	dB	The difference in decibels between the insertion loss and the spurious signal in the stopband.
	Input/Output Impedance	—	Ohm	Internal impedance value of the input and output of the ceramic filter
	Selectivity	—	dB	The ability of a filter to pass signals of one frequency and reject all others. A highly selective filter has an abrupt transition between a passband region and the stopband region. This is expressed as the shape factor—the attenuation bandwidth divided by the pass - bandwidth. The filter becomes more selective as the resultant value approaches one.

On the other hand, if R_1 and R_2 are connected to higher values other than those specified, the insertion loss will increase, the center frequency will shift toward the high side and the ripple will increase.

DEALING WITH SPURIOUS RESPONSE

Frequently in using 455kHz filters, spurious will cause problems due to the fact that the resonance occurs under an alien vibrating mode or overtone deviating from the basic vibration characteristics. Among available solutions for dealing with spurious response are:

1. The use of a supplementary IFT together with the ceramic filter for suppression of the spurious.
2. The arrangement of two or more ceramic filters in parallel for the mutual cancellation of spurious.
3. The addition of a low-pass or high-pass LC filter for suppression of spurious. Perhaps the most commonly used method of dealing with spurious is the use of a supplementary IFT in conjunction with the ceramic filter. The before and after effects of the use of an IFT are shown in Figs. 429-10 and 11. In Fig. 429-10, only a single SFZ455A ceramic filter is employed and spurious is a significant problem. With the addition of an IFT, the spurious problem is reduced as is shown in Fig. 429-11.

Although spurious is a significant problem to contend with when using 455kHz ceramic filters, it is not a problem in 4.5MHz and 10.7MHz ceramic filters, as their vibration modes are significantly different.

CONSIDERATIONS FOR GAIN DISTRIBUTION

Since the impedance of both the input and output values of the ceramic filters are symmetric and small, it is necessary that the overall gain distribution within the circuit itself be taken into consideration. For instance, in the discussion concerning proper impedance matching, it was illustrated that a certain DC loss occurs if the recommended resistance values are not used. This can cause an overall reduction in the gain which could present a problem if no allowances have been made for the corresponding loss. To compensate for this problem, it is recommended that the following be done:

1. The amplifier stage should be designed to compensate for this loss.
2. The ceramic filter should be used in combination with the IFT for minimizing both matching and DC losses. The IFT should be used strictly as a matching transformer and the ceramic filter only for selectivity.

As the use of IC's has become more prevalent with ceramic filters, these considerations have been taken into account. It should be noted that few of the problems discussed above have been realized when more than three (3) IF stages have been employed.

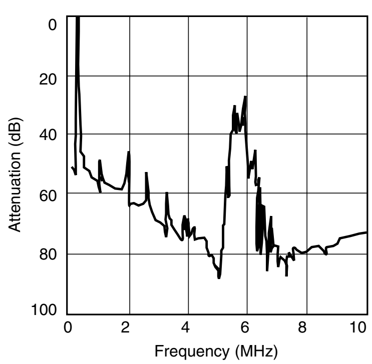

Fig. 429-10
Spurious Response With Model SFZ455A Ceramic Filter

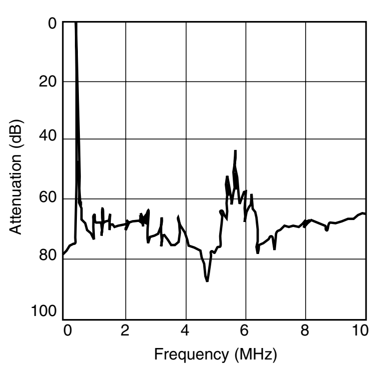

Fig. 429-11
Spurious Response With Model SFZ455A Ceramic Filter And IFT

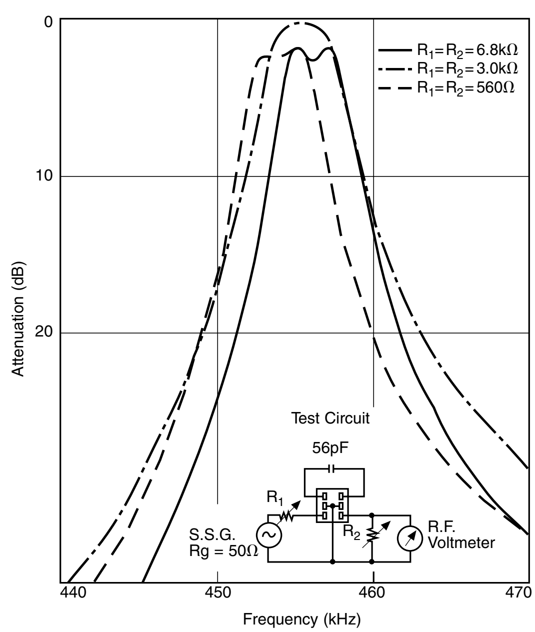

Fig. 429-12
Model SFZ455A Ceramic Filter Matching Impedance vs. Pass-Band Characteristics

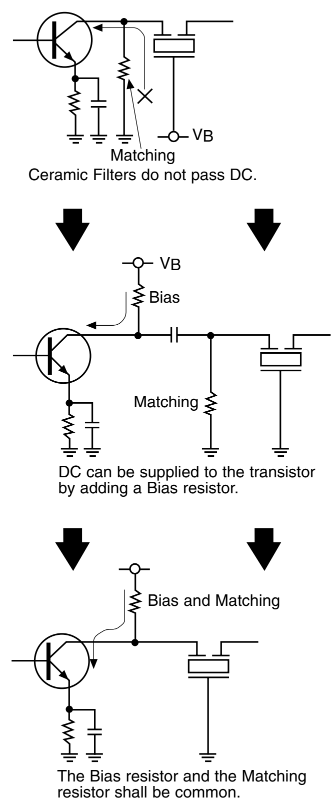

Fig. 429-13
Coupling With A Transistor

CERAMIC FILTERS DO NOT PASS DC

It is important to note in designing circuits that ceramic filters are incapable of passing DC. As is illustrated in Fig. 429-13, in a typical circuit where a transistor is used, a bias circuit will be required to drive the transistor. Since the ceramic filter requires matching resistance to operate properly, the matching resistor shown in the diagram can play a dual role as both a matching and bias resistor.

If the bias circuit is used, it is important that the parallel circuit of both the bias resistance and the transistor's internal resistance be taken into consideration in meeting the resistance values. This is necessary since the internal resistance of the transistor is changed by the bias resistance. However, when an IC is used, there is no need for an additional bias circuit since the IC has a bias circuit within itself.

Here it is recommended that an IFT be used for impedance matching with the ceramic filter when coupling with a mixer stage, as shown in Fig. 430-14.

COUPLING CAPACITANCE

The SFZ455A is composed of two filter elements which must be connected by a coupling capacitor. Moreover, the frequency characteristic changes according to the coupling capacitance (Cc). As shown in Fig. 430-15, the larger the coupling capacitance (Cc) becomes, the wider the bandwidth and more the ripple increases. Conversely, the smaller the coupling capacitance becomes, the narrower the bandwidth becomes and the more the insertion loss increases. Therefore, the specified value of the coupling capacitance in the catalog is desired in determining the specified passband characteristics.

GROUP DELAY TIME CHARACTERISTICS

Perhaps one of the most important characteristics of a transmitting element is to transmit a signal with the lowest possible distortion level. This distortion occurs when the phase shift of a signal which passes through a certain transmitting path is non-linear with respect to the frequency. For convenience, the group delay time (GDT) characteristic is used for the purpose of expressing non-linearity.

It is important to note the relationship between the amplitude and the GDT characteristics when using group delay time terminology. This relationship differs depending upon the filter characteristics. For example, in the Butterworth type, which has a relatively flat top, the passband is flat while the GDT characteristic is extremely curved, as shown in Fig. 430-16. On the other hand, a Gaussian type, is curved in the passband, while the GDT characteristic is flat. With the flat GDT characteristics, the Gaussian type has excellent distortion characteristics.

Since the amplitude characteristics for the Butterworth type is flat in the passband the bandwidth does not change even at a low input level. With the amplitude characteristic for the Gaussian type being curved in the passband, the bandwidth becomes narrow at a low input level and the sensitivity is poor. Therefore, it should be noted that the Gaussian type has a desirable distortion factor while the Butterworth type has the desirable sensitivity.

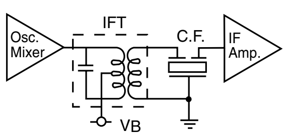

Fig. 430-14
Coupling From Mixer Stage

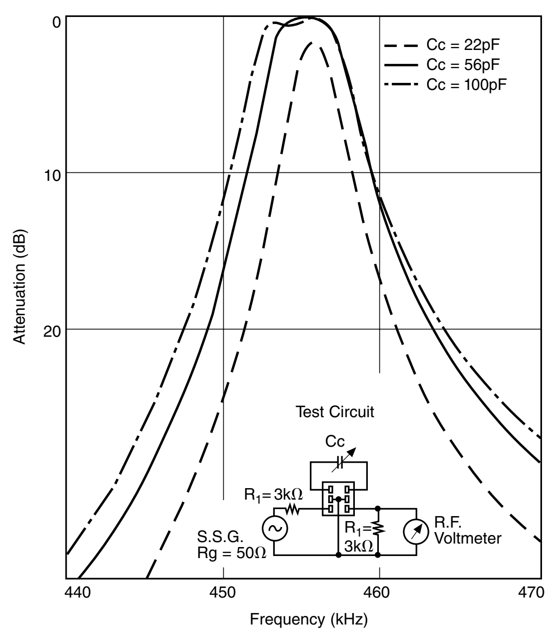

Fig. 430-15
Model SFZ455A Ceramic Filter Coupling Capacitance vs. Passband Characteristics

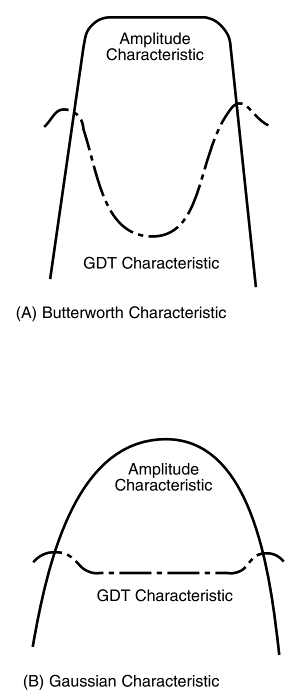

Fig. 430-16
Relationship Between Amplitude And GDT Characteristics