With the rapid growth and increasing sophistication now taking place in all phases of the communication industry, there is a great demand for cost effective bandpass filters that offer state-of-the-art performance.

ECS has a wide offering of filters utilizing the following technologies:

- Monolithic Crystal Filters (MCF)
- Ceramic Filters
- Surface Acoustic Wave (SAW) Filters

These three technologies are utilized over the frequency range where they will offer a highly consistent performance and have exceptional long-term reliability at the lowest possible cost. Each technology offers certain advantages at the frequency range where they are used, additional information about each filter technology is discussed below. Be sure to familiarize yourself with the typical filter amplitude frequency response curve, which is shown below (Fig. 1).

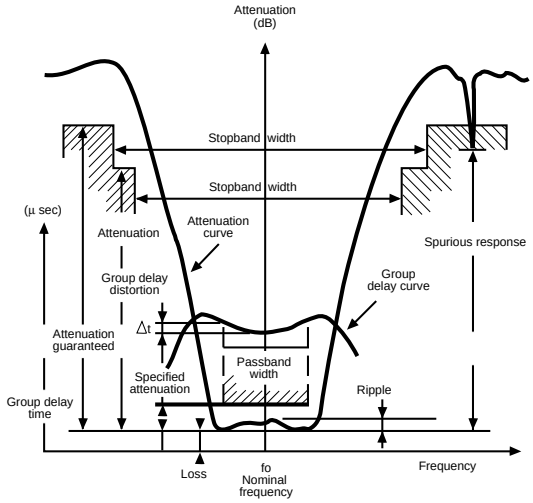
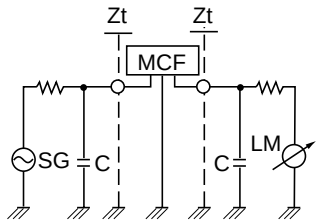


Figure 1)

Monolithic Crystal Filters (10.7 ~ 110MHz): Crystal Filters have very high Q's and excellent temperature and aging characteristics. These benefits result in filters that offer very narrow bandwidths and are highly selective.

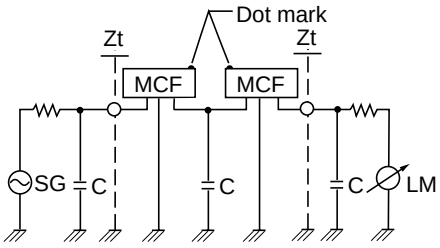
The two-pole monolithic filter is the basis for all packaged crystal filters. Compared to a discrete crystal filter a single monolithic dual resonator replaces two discrete crystal units, a balanced transformer, and a trimmer capacitor. This results in a monolithic crystal filter being smaller and more cost effective than discrete crystal filters. MCF's use fewer components and have fewer interconnections so MCF's tend to be more reliable, while eliminating balanced transformers reduces loss and improves stability compared with discrete filters.

With the addition of coupling capacitors between two-pole sections, they can be cascaded to produce four, six and eight or more pole filter responses (see figure 2 & 3 for MCF Test Circuits).



2-POLE MCF
Zt: Terminating Impedance

Figure 2)



4-POLE MCF
Zt: Terminating Impedance

Figure 3)

The typical shape factor that can be achieved from a given number of poles with monotonic filters is shown below in Table 1).

NUMBER OF POLES	SHAPE FACTOR (60/3 dB)
2	30
4	5
6	2.5
8	1.9

Table 1)

There are two basic problems associated with crystal filters: spurious responses and non-linear drive level responses.

The spurious responses are caused by, anharmonic resonances normally occurring just above the desired resonance as well as near harmonic overtone responses. The spurious region appears in the filter as narrow responses of reduced attenuation.

The non-linear drive level response limits the drive level to a maximum of +10 dBM with a recommended drive level of –10 dBM Max. Unless the crystals are carefully designed and manufactured the Q and frequency can change as a function of drive and the Q could have as the drive level was changed from –10 to –60 dBM. Since MCF's must operate over a wide drive level ranges they should be tested over expected drive level conditions.

The non-linear drive condition is the main cause of intermodulation distortion (IMD) in crystal filters. IMD can be measured using the circuit shown in Fig. 4).

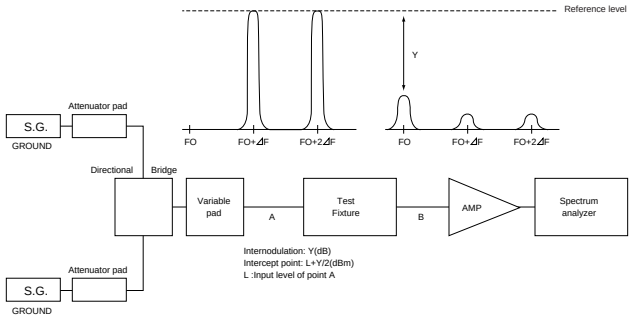


Figure 4)

ECS produces monolithic crystal filters for a wide range of uses, including narrow and intermediate band filters for mobile, UHF, and cordless telephones and single side band applications. ECS also offers several different package types including true SMD, surface mount (jacket type) and thru-hole monolithic crystal filters.

Ceramic Filters (450 KHz ~ 10.7): The most obvious advantage of a ceramic filter is the small size and lightweight for compact applications. These filters also have low loss, good waveform symmetry and high selectivity. All ceramic filters derive their basic frequency selectivity from mechanical vibration resulting from the piezoelectric effect. Since these devices are produced in large volumes they are very uniform which makes them ideal for large volume production designs.

Traditionally, nearly all low and high-end AM and FM commercial radios use ceramic bandpass filters. However, applications are also found in cordless telephones, cellular systems, 2-way communications, and the television industry. ECS, INC has been able to develop a complete line of practical, inexpensive ceramic filters for entertainment and communication applications.

It is imperative to properly match the impedance. Without the proper impedance matching, the operational characteristics of the ceramic filter can not be met. Figure 5 illustrates a typical test circuit. For instance if R1 and R2 are connected to lower values than specified, the insertion loss increases, the center frequency shifts towards the low side and the ripple increases. On the other hand if R1 and R2 are connected to a higher value than those specified, the insertion loss will increase, the center frequency will shift toward the high side and the ripple will increase.

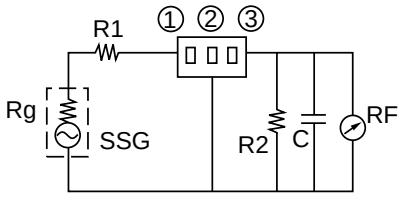


Figure 5)

It is also important to note that in designing circuits that ceramic filters are incapable of passing DC. 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 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 additional bias circuit since the IC has a bias circuit within itself.

Surface Acoustic Wave (SAW) Filters: (82-470MHz) There are many advantages to a SAW filter such as their compact package size which also results in a device that is very rugged. The fact that a SAW filter does not require tuning also means that it will not be de-tuned in the field thus making the device more reliable.

SAW filters are available at higher frequencies than MCF's and offer either narrow or wide bandwidths with very good selectivity.

Surface acoustic waves are mechanical (acoustic) rather than electromagnetic. In SAW devices, piezoelectric materials are required to convert the incoming electromagnetic signal to an acoustic one and then back to electromagnetic. The SAW filter is generally categorized as follows:

- Transversal type filter consisting of a pair of IDTs on a piezoelectric substrate (Fig. 6).
- Resonance type filter consisting of SAW resonators that are electrically or acoustically combined (Fig. 7 & 8).

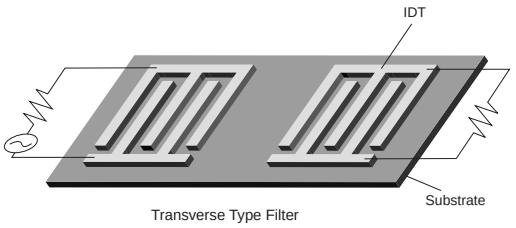


Figure 6)

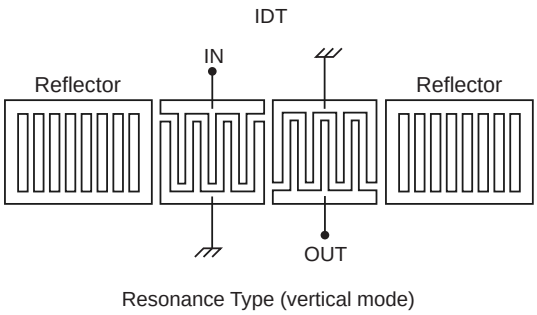
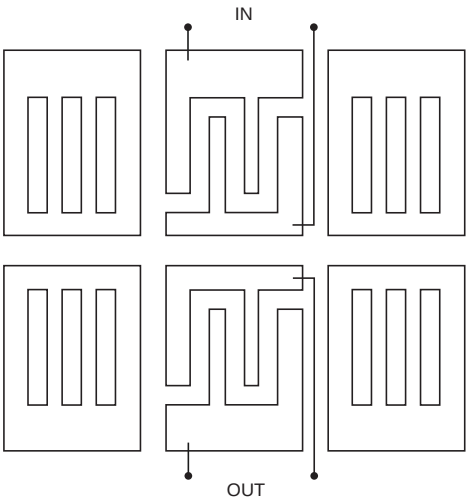


Figure 7)



Resonance Type (horizontal mode)

Figure 8) Resonance Type

Table 2) shows the major features of the two different type filters. The piezoelectric materials used to establish a SAW device are quartz crystals such as mono-crystals, or membranes of ZnO or similar substance.

FILTER TYPE	% BANDWIDTH	INSERTION LOSS
Transversal	0.3 ~ 30%	5 ~ 16
Resonance	0.02 ~ 0.3%	5 ~ 4

Table 2) Features of SAW Filters

At ECS INC, electrode configuration and substrates are selected according to the customer's requirements. Detailed design is conducted through computer simulation. These devices are generally used for a variety of RF/IF filters focused mainly on mobile communication applications such as pagers, portable phones, timing re-timing filters for optical communication, wireless local loop and spread spectrum communications.

Definitions

The following definitions will aid you in understanding filter performance for all types of filters.

Center Frequency (Fo): The arithmetic mean between the high and low cut off frequencies of a filter.

Bandwidth (BW): The difference between two cut off frequencies at a specified attenuation level (Usually 3 dB or 60 dB).

Attenuation: Reduction of signal in transmission through a filter. Attenuation is usually expressed in decibels (dB).

Decibel (dB): Unit that expresses the ration between two powers, two voltages or two currents.

$$\left(10 \text{ Log } \frac{P_1}{P_2}, 20 \text{ Log } \frac{V_1}{V_2} \text{ or } 20 \text{ Log } \frac{I_1}{I_2}\right)$$

Shape Factor (SF): Ratio of bandwidths at two different levels of attenuation.

Stop Band: The area of frequency where it is desirable to reject or attenuate all signals as much as practical. Also called reject band. Expressed as a range of frequencies attenuated by more than some specified minimum, such as 60 dB.

Ripple: The wavelike response in the passband of a filter (expressed in dB). Unless otherwise specified the maximum ripple will be that excursion from the highest peak to the lowest valley.

Insertion Loss (IL): Power loss of the filter in the passband (expressed in dB). Zero dB reference shall be the point of maximum output of the filter unless it is specified otherwise.

Insertion Loss = 10 Log Pin/Pout

Source Impedance (Input Termination): The output impedance of the circuit that drives the filter.

Load Impedance (Output Termination): The impedance that must be connected to the output terminals of the filter in order to achieve the proper response.

Spurious Mode: Unwanted responses that occur in the filter due to resonant frequencies of the resonator other than the fundamental frequency.