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CRYSTAL FILTER APPLICATION

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Crystal filters offer the narrowest bandwidths and best temperature and long term stabilities of any bandpass type filters. These filter characteristics result from the very high Q and excellent stability of the quartz crystals which are used as resonators in the filter circuits. Filters employing quartz crystals provide the ultimate in performance for very narrow bandwidth applications.

The lowest cost filter designs, the so-called “narrowband” designs, can be used for bandwidths up to a maximum of about 0.3% of center frequency. Wider bandwidths can be achieved by adding inductors to essentially tune out part or all of the shunt capacitance of the crystals. These “intermediate bandwidth” designs are useful up to about 2% of the center frequency although most applications are in the 0.3 to 1% range. In very restricted frequency bands, “wideband” designs can be used to provide bandwidths up to 3 to 4% by combining crystal resonators with L/C resonators. Crystal filters can also be built using 3^{rd} overtone crystals although only in much narrower bandwidth applications. A chart illustrating the bandwidth and frequency ranges achievable with crystal filters is shown in Figure 1.

The traditional “discrete” crystal filter uses individual crystal resonators and consists of an assembly of crystals, capacitors, and RF transformers mounted on a PC board. Each crystal is individually manufactured to a specific frequency and mounted in a hermetically sealed container. Because the crystals can be built to any desired frequency, a wide variety of filter designs are possible. Designs have been developed which can provide filters with Butterworth, Chebyshev, Bessel, or elliptic-function responses as well as skewed (single-sideband) characteristics. In addition, a variety of techniques are available for building filters with linear-phase or phase compensated characteristics. This exceptional design flexibility makes the discrete crystal filter very attractive for specialized requirements. Also, because the filter is essentially a PC board assembly of individual components, the cost of tooling is minimal: an important factor for small quantity orders.

Crystal filters are also available as “monolithic” type devices in which multiple resonators are fabricated on a single quartz wafer. These resonators are acoustically coupled to each other to provide a multi-pole filter response. The monolithic device provides a complete filter and requires no additional components except for terminating networks. Monolithic filters are typically manufactured at frequencies of 5 MHz and higher with bandwidths comparable to narrowband discrete filter designs.. These filters are most commonly fabricated as 2-pole devices and can be easily cascaded to provide higher order filter designs. Monolithic crystal filters are considerably less costly to manufacture then comparable discrete filter designs. However, custom tooling and specialized fabrication equipment are required for their production. As a result, the cost of developing custom designs can only be justified for high-volume applications.

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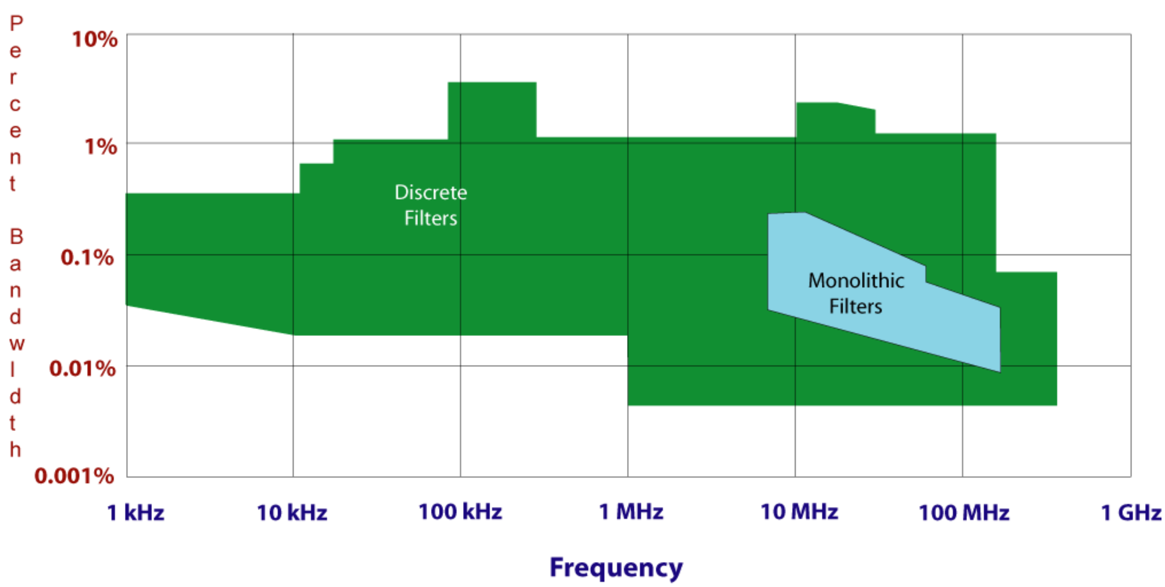
The major application for crystal filters is to provide narrow-band IF selectivity in various communications receivers. Typical receivers use anywhere from six to ten poles of selectivity which is supplied with all crystal filters or with a combination of crystal and ceramic filters. Probably the largest single usage is in analog cellular telephones, which use a deviation of ±12 kHz deviation with typical bandwidths of 30 kHz. Common IF frequencies are 45 MHz and higher frequencies in the 70 to 90 MHz region. Conventional two-way FM radios use a deviation of ± 5 kHz with bandwidths of 12 – 13 kHz and one-half of those values for split channel applications. Common IF frequencies are 10.7 and 21.4 MHz. Digital cellular telephones use a variety of IF bandwidths dependent on the particular operating system. Crystal filters are commonly used in single-sideband radio exciter applications for selecting the desired sideband. These filters typically are 2 to 3.5 kHz wide and have been built at center frequencies ranging from 1 to 10 MHz. Most designs provide six to eight poles of selectivity.

A rapidly expanding field for narrow-band receivers is in the area of remote sensing applications. A wide variety of systems are used with a range of IF bandwidths that can be supplied by crystal filters. Other applications for crystal filters include narrow-band filtering and filter banks for use in a variety of test equipment such as spectrum analyzers and vector voltmeters. Some specialized filters are used in data transmission systems where very flat time delays are required. Most of these applications are relatively low quantity and are ideally suited to discrete crystal filter designs with their low up-front tooling costs.



Bandwidth-Frequency Chart for Crystal Filters
FIGURE #1