Crystal Filter Glossary

Linear Phase

Family of filters, including Gaussian, Bessel and their derivatives, all roll off slowly at the band edge and consequently have reduced or minimal delay peaks. The rounded passband of these filters occurs because power is reflected to the source as frequency deviates from nominal center frequency. Consequently, the return loss of these filters is poor away from center frequency. Classical network theory shows that sensitivity to changes in element values accompanies poor return loss. Consequently this family demands tighter control of components and delay performance often departs from theoretical predictions. This sensitivity also results in increased manufacturing cost. In general, these designs work more predictably if the number of poles are restricted.

Intermodulation (IM)

Occurs when a filter acts in a nonlinear manner causing incident signals to mix. The new frequencies that result from this mixing are called intermodulation products. They are normally third-order products, and for 1 dB increase in incident signal levels, the IM products increase by 3 dB. Out-of-band intermodulation occurs when two incident signals (typically -20 to -30 dBm) in the filter stopband produce an IM product in the filter passband. This IM is most prevalent in receiver application when an input signal is present simultaneously in the first and second channels adjacent to the passband of the filter. The IM performance of crystal filters at low signal levels is determined by surface defects associated with the resonator manufacturing processes and is not subject to analytical prediction. In-band modulation occurs when two closely spaced signals within the filter passband cause IM products that are also within the filter passband. It is most prevalent in transmit applications where signal levels are high, typically between -10 dBm and +10 dBm, but it can also occur in some receiver applications. The IM performance at high signal levels is a function of both the resonator manufacturing processes and nonlinear elastic properties of quartz. The latter is dominate at higher signal levels, and can be analyzed.

Input & Output Impedance

Impedances presented by the filter to the outside world. They normally have both resistive and reactive components and change with frequency. The impedances may be expressed in terms of VSMR, return loss, resistance and reactance or magnitude and phase angle. Sometimes a user may wish to specify return loss of VSWR limits. Under these circumstances it is important to remember that all commonly used crystal filter designs are based on reflective rather than absorptive theory. This is demonstrated by the stopband products by an ideal lossless filter. Since a lossless filter can have no resistance to absorb power, it must attenuate by reflecting power. For example, at the 3 dB passband edge, half of the incident power is reflected; the return loss has already reduced to 3dB and the VSWR is 5.8:1. From this it can be appreciated that constant impedance is impossible to achieve except by the incorporation of loss pads or compensation networks. The problem is usually exacerbated when the effects of dissipation are included. Specifications on return loss and VSWR are best restricted to the flat portion of the filter response in the center of the passband and should make allowance for filter component tolerances as well as non-ideal terminations.

Vibration-Included Sidebands

May appear on a crystal filter output signal when the filter is subject to acceleration forces due to vibration. Quartz crystal resonators, being piezoelectric devices, convert mechanical to electric energy. Therefore, the resonant frequency of a crystal is modulated at the frequency of vibration. The peak deviation of this frequency modulation is determined by the acceleration sensitivity of the crystal and the amplitude of vibration. If all crystals in a filter deviate by the same amount and the same time (i.e. in phase with each other) the filter response will oscillate about the nominal center frequency at a rate equal to the frequency of vibration. Because the insertion phase shift of the filter is a function of frequency, as the filter changes frequency the phase shift imposed on a CW signal will also change, i.e., the CW signal will be phase modulated at the frequency of vibration. In most instances, the crystal frequency is deviated a fraction of a ppm. Filter bandwidths are comparatively wide with a corresponding low insertion phase slope; consequently, the phase-modulated sidebands are often of no concern. However, narrowband spectrum clean up filters may require special attention. Sideband generation is minimized by minimizing the acceleration sensitivity of the resonator and by control of mechanical resonances within the filter structure. Reduction of resonator acceleration sensitivity is a current research topic in a number of organizations.

Phase Noise

Can be introduced by a crystal filter under static conditions as well as under vibration. It is associated with resonator defects and can be minimized by proper processing and is generally confined to the passband. Crystal filters can, however, improve the phase noise floor for crystal oscillators.

Noise Bandwidth

The noise bandwidth is the band width of an ideal filter which would pass the same amount of white noise as the filter under test. The noise bandwidth indicates power at the filter output, hence often serves as a performance measure for comparing filters. The noise band width is primarily controlled by the passband. The Butterworth and Chebychev family of filters, because of their more rapid transition from passband to stopband, have a smaller noise bandwidth than do that flat delay type filters.