Specifying the Proper SAW Filter

Spectrum Microwave offers a wide range of high-quality standard and custom SAW filter product solutions, designed and manufactured utilizing state of the art semiconductor fabrication techniques. The company's flexible approach, high volume capability and worldwide support makes Spectrum Microwave the SAW filter supplier of choice for RF engineers in many of the world's leading communications and consumer electronics companies.

Today's crowded radio frequency spectrum, from baseband through 3 GHz, requires system designers to meet stringent regulatory requirements without sacrificing performance. Filter requirements demand high selectivity, low insertion loss, flat passbands and uniform group delay to meet performance criteria. In addition, these filters must be highly repeatable, small size, low cost and operate in adverse environmental conditions. Surface acoustic wave (SAW) filters are a perfect match to such requirements.

There are a multitude of commercial applications for SAW filters. They include, but are not limited to, telecommunications (base station and handheld), WiMAX, set-top box and cable modems, navigation (GIS/GPS), automotive, and medical. There are also space and military applications, including functions from simple time delay to dispersive devices for complex matched filtering applications.

Unlike conventional RF filters that depend on electrical parameters, such as inductance and capacitance, SAW filters depend on the mechanical properties of piezoelectric crystals. Through transducers deposited on the crystal, SAW devices convert an RF signal into a mechanical displacement, creating a surface wave across the device and then convert back again into an RF signal. The filtering characteristics of SAW devices depend on the well-known properties of the selected crystalline material, the length of total displacement, and the design, placement and thickness of the transducer. As a result, SAW filters can be readily fabricated using modern semiconductor manufacturing techniques to an accuracy that is impossible to match using electronic components.

Specifying the Proper Filter

Although SAW devices can greatly simplify RF filter designs, their successful use does require that they be properly specified. In addition to providing the center frequency and bandwidth for the filter, designers should consider a number of other factors that may affect system operation. These include the SAW filter's insertion loss, signal group delay, out-of-band rejection ratio and thermal stability as well specifying the allowable ripple in the amplitude, phase and group delay responses. These factors affect the filter's in-system operation as well as cost, and interactions among some of the factors may require that designers make tradeoffs.

A typical filter is shown in figure 1. The wide (20 MHz to 2.6 GHz) operating range of SAW filters makes specifying the center frequency (CF) and the filter bandwidth (PW) quite straight forward. Other parameters, however, are more constrained. The stopband level (SL), for example, is limited by the device's ability to dampen undesired vibrations. The typical value achievable is about -55 dB to -60 dB. If a design requires greater rejection, two or more SAW filters must be run in cascade, either in the same package or as two separate devices. Two cascaded filters will achieve -70 dB to -80 dB, but the cost of cascading to increase rejection is accumulating insertion loss.
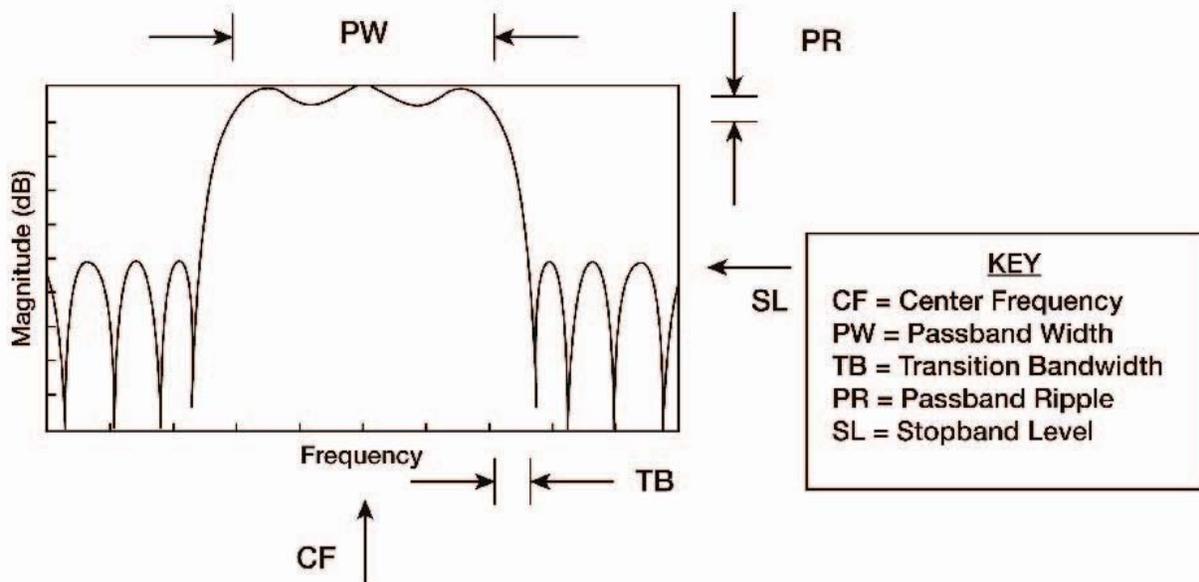

Figure 1: Characteristics of typical SAW filter

Insertion loss in SAW devices is a key parameter because these devices are passive; there is no internal amplification to compensate for the energy lost in the piezoelectric coupling that converts the signal between electrical and mechanical forms of energy. The magnitude of the insertion loss is principally a function of filter bandwidth along with the crystalline material used (see table 1).

Material	SAW Velocity (meters/sec)	Piezoelectric coupling	1st Order Temperature (ppm/C˙)
Quartz ST-X	3157	0.116 (higher IL)	0 best
Lithium Tantalate LiTa03	3299 Lowest Group Delay	0.75	18 better
Lithium Niobate LiNb03	3076	5.7 (lower IL)	75 good

Table 1: Insertion loss of different crystalline materials

However, material choice affects more than insertion loss. One significant material-dependent factor is the filter's group delay. The time required for a signal to pass through the filter is determined by the wave's velocity through the material as well as the filter length. For a given filter length, then, material choice requires making a tradeoff between insertion loss and group delay. Another primary factor in choosing a substrate material is the fractional bandwidth (FBW) of the device. The relationship between the FBW and the substrate is a function of the piezoelectric coupling factor, which is a measure of the coupling between an applied voltage and the resulting mechanical stress.

Because group delay depends on material-dependent wave velocity and filter length, SAW device designers can ameliorate the loss-delay tradeoff somewhat by shortening the filter to reduce delay. The slope of the filter's transition from pass-band to rejection, however, depends on filter length. The longer the filter, the more surface barriers can be placed to attenuate unwanted frequencies and the sharper the cutoff. Thus, group delay, insertion loss and filter cutoff slope along with package size are all intertwined.

The filter's temperature stability is also related to material choice, further complicating the tradeoffs. Quartz is the most stable, with no first-order temperature-dependent variation but the highest insertion loss. Other materials offer insertion loss or less group delay at the cost of increased temperature sensitivity.

Simulation Simplifies Tradeoff Analysis

Although system designers should understand how SAW filter design choices affect various parameters, they do not need to try making these tradeoffs by trial and error. Customers working with vendor support, such as the SPECTRUM MICROWAVE team of worldwide field applications engineers and factory engineers, can be assured that their requirements will be simulated through the design process. Such simulations provide customers with accurate performance estimates for various design choices. Knowing the types of tradeoffs that will be necessary, however, ensures developers can successfully define achievable specifications and achieve those specifications the first time.

There are many other factors that potential SAW filter users may want to consider. One is power level. Because SAW filters depend on mechanical motion, there are limits to how much energy they can handle. Typical filters can handle as much as 1W of signal energy. However, with special material doping, this limit can be extended.

Packaging is another choice that must be considered. Often, package size is one of the first parameters that customers specify. Too strict a size limit, however, can constrain the filter cutoff slope, which is a function of device length, and may prevent the SAW device from fitting into the desired package.

Although these many tradeoffs may seem daunting, SAW filters still offer much higher performance and design simplicity than electronic filtering. Filter manufacturers can work with system developers to create filters with an optimum set of characteristics for the application. Developers who understand the nature of the tradeoffs, however, will be able to achieve that optimum condition faster and with no unexpected byproducts of the design choices.

SAW Filters from SPECTRUM MICROWAVE

SPECTRUM MICROWAVE standard and custom SAW filter product solutions are designed and manufactured utilizing advanced state of the art semiconductor manufacturing techniques to meet the demanding criteria expected by customers. Whether a design is for high volume commercial applications, such as bandpass filters, diplexers to meet stringent operational and regulatory requirements or more complex SOC hybrids combining SAW filters with other devices in a single hybrid package, SPECTRUM MICROWAVE gives customer requirements the highest priority.