The Need for High Frequency "Brick Wall" Filters

Important for ADC/DAC Testing

Introduction

In a prior Tech Tip (March 2020) we discussed the benefits of low Total Harmonic Distortion (THD) filters for Analog to Digital Conversion and Digital to Analog Conversion (ADC/DAC) testing applications. THD filters are utilized in industry to clean signal sources or test generators by removing the harmonics of the test signal or signal generator that might otherwise interfere with test results.

In this December 2020 Tech Tip we will discuss the need for high frequency filters with "brick wall" characteristics for a variety of applications including ADC/DAC testing applications, in response to the industry's ongoing trend toward higher and higher testing frequencies amidst the performance limits of traditionally utilized filter designs.

Background

Aliasing occurs when a signal processing test system acquires data at an insufficient sampling rate (F_s). If a signal contains any frequencies greater than Nyquist ($F_s/2$) they are mixed with the sampling frequency in the converter's sampler and mapped to frequencies less than the Nyquist frequency. This causes these different signals to become mixed and thus, indistinguishable from each other (aliases of one another) during sampling. For more information about sampling theory basics, please refer to the references on p.3.

Simply stated, the Nyquist criterion requires that *the sampling frequency be at least twice the highest frequency contained in the signal, or information about the signal will be lost.*

High-quality sampling systems ensure that no aliasing occurs by the insertion of a filter effectively filtering the signal of interest (cutoff frequency being around the Nyquist frequency) before sampling.

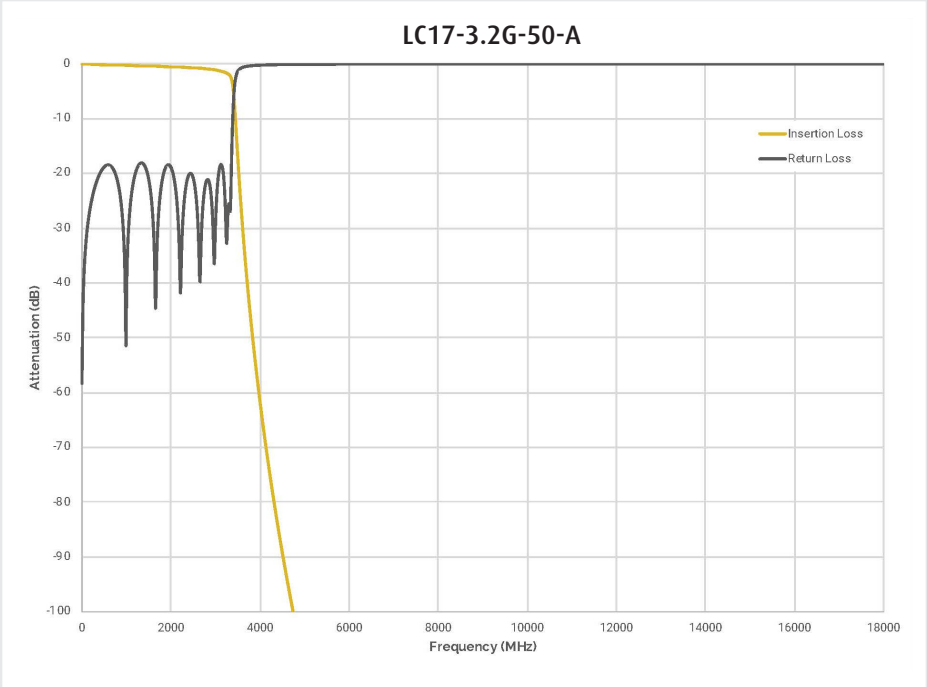
The Challenge

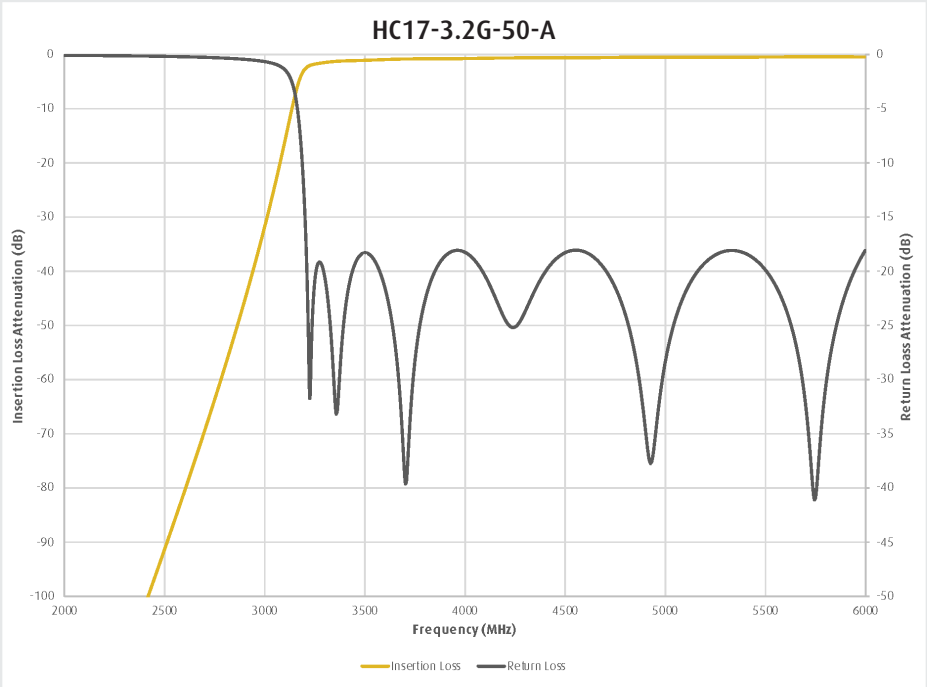
For ADC/DAC test and measurement applications where aliasing must be avoided, anti-aliasing high performance filters are key to a successful test setup. Anti-aliasing Elliptical Function lowpass or highpass filters are traditionally specified for use in such data acquisition systems to ensure that all sampled signals of interest can be reconstructed accurately. This is especially important when testing semiconductor chips and integrated circuits.

Anti-aliasing Elliptical Function filters provide excellent passband to stopband attenuation performance and are ideal for ADC/DAC test setups. These filters are often referred to as "brick wall" filters since their steep roll-off/cutoff slope (passband to stopband attenuation) resembles a brick wall; they are commonly designed in digital form (e.g. Finite Impulse Response or FIR filters). These Elliptical Function filters are typically available for frequency ranges from 1kHz to 500MHz. That upper limit is unfortunately well below the GHz levels that are becoming increasingly popular in the ADC/DAC signal conditioning testing industry, and which are forecasted to continue to trend higher. So the challenge is to design a filter with brick wall characteristics that can perform in the GHz range.

The Solution

The Chebyshev filter is considered the “workhorse” of all the common filter topologies. Its response is easily attained with few components and it offers very good selectivity with one of the steepest roll-off responses of the group. GCG (through its TTE affiliate) has successfully leveraged the Chebyshev “workhorse” topology in a 17th order lowpass (and highpass) design to address the need for “brick wall” characteristics with frequency performance to 7GHz. TTE’s new LC17 (Chebyshev lowpass) and HC17 (Chebyshev highpass) series, while not true brick wall filters, are designed in a way that they have steep roll-offs that closely resemble brick wall filters. *Refer to graphs below*. Since these filters are based on Chebyshev topology they have a slight ripple in the passband and no ripple in the stopband, unlike elliptical designs which have ripple in both the passband and stopband.





Brick Wall Filters to 7GHz

TTE's new LC17 and HC17 Chebyshev "brick wall" filter series provide the following characteristics:

	LC17T*	HC17T*
Description	Chebyshev Lowpass Filter	Chebyshev Highpass Filter
Frequency Range	1MHz to 7GHz	1MHz to 7GHz
Passband to Stopband	-50dBc at 1.19 x f_0 -60dBc at 1.27 x f_0	-50dBc at 0.84 x f_0 -60dBc at 0.78 x f_0
Performance	"Brick Wall" performance similar to Anti-aliasing Elliptical Function filter	"Brick Wall" performance similar to Anti-aliasing Elliptical Function filter
Cases	Standard or Custom cases available	Standard or Custom cases available
Standard Case Dimensions		
Length	2.00 in.	1.32 in.
Width	0.375 in.	0.400 in.

** TTE's "T" option, when specified, refers to a filter designed for optimum Total Harmonic Distortion (THD). Optimum THD performance: -80dBc minimum, -96dBc typical and greater than -115dBc in some instances.*

Figure 1
LC17-3.2G-50-A
(case dimensions listed in table above)

Figure 2
HC17-3.2G-50-A
(case dimensions listed in table above)

Note: Elliptical filters have a more complex network than the Chebyshev, requiring more components, which compromises their phase response when compared to the Chebyshev design. So the Elliptical filter is best suited for applications where selectivity is a key driver in the filter design since its ripple amplitude of the passband and stopband can be adjusted separately to fit the application.

IN CONCLUSION

Anti-aliasing Elliptical Function filters provide excellent passband to stopband attenuation performance and are typically ideal for ADC/DAC test setups since these "brick wall" filters provide a desirable steep roll-off/cutoff slope (passband to stopband attenuation). However, with their performance typically limited to frequencies below 500MHz, they are not necessarily ideal when higher frequencies are required, as seen with recent industry trends. To address the testing community's demanding needs for higher frequency brick wall filters, TTE has designed a 17th order Chebyshev filter with brick wall characteristics, appropriate for frequencies up to 7GHz.

REFERENCES

1. "AN-236 An Introduction to the Sampling Theorem", Application Report SNAA079C, May 2004, Texas Instruments
2. "What the Nyquist Criterion Means to Your Sampled Data System Design", MT-002 Tutorial, October 2008, by Walt Kester, Analog Devices

HELPFUL INFORMATION

- TTE'S Chebyshev Lowpass/Highpass Filters to 7GHz:
  (LC17 and HC17 are included in LC and HC series below, respectively)
  - Series Information
    - LC Series
    - HC Series
  - Series Datasheet
    - LC Series
    - HC Series
- TTE'S Anti-aliasing Elliptical Function Lowpass/Highpass Filters:
  - Series Information
    - LE Series
    - HE Series
  - Series Datasheet
    - LE Series
    - HE Series
- March 2020 Tech Tip: "Benefits of Low THD Filters for ADC/DAC Testing"
- TTE's Low THD Filter Series: http://tte.com/search-for-low-thd-filters/
- THD Test Procedure: http://tte.com/wp-content/uploads/THD-Test-Procedure.pdf

Additional filters are available from TTE's sister companies Microwave Circuits (microwave and RF filters) and Instec Filters (EMI/RFI fitlers).

To access downloadable versions of this and prior technical tips please click here.

If you have any questions about this Technical Tip, suggestions for future Technical Tips, or need assistance with our standard or custom products, please contact us.

Gowanda Components Group
sales@gowanda.com
+1-716-532-2234

www.GowandaComponentsGroup.com