

ADC TEST USING FILTERING AND DIGITAL CORRECTION

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Abstract: The combination of two methods enable to decrease an influence of testing signal distortion for testing of the dynamical quality of middle resolution AD modules in frequency range from several tens of kHz to several MHz is described. In the first step, the distortion of a generated testing signal is suppressed by applying a low distortion LC filter special designed for this purpose. It decreases all spurious components and also even harmonic components of the generated signal, but further odd harmonic component arise due to applying a ferromagnetic material in the used coils. However, in combination with the modified FFT method (spectrum correction test) these undesirable harmonic components can be digitally corrected.

Keywords: testing signal distortion, filter

1 INTRODUCTION

Well known testing methods (FFT Test, Best Sinusoidal Curve Fit Method, Histogram Test) standardized in the IEEE Standard for Digitizing Recorders [1], and in the draft of IEEE Std 1241 use the sine wave as the testing input signal. It is recommended to use a generator with the THD (Total Harmonic Distortion) about 10 dB better than the SNR (Signal to Noise Ratio) of the tested ADC there. However, it makes great difficulties to use these methods in the frequency range from several tens of kHz to several MHz, where middle resolution (12 - 16 bits) AD modules are frequently used, but no commercially available generator with THD less then -100 dB exists.

One solution, how to solve it, consists of a digital correction of the known distortion of the testing signal. The both harmonic and spurious components (in complex form) of the testing signal are analyzed and corrected (see [2], [3]). However, some problems can arise by applying this method, when many significant spurious components are present in the testing signal.

Another possibility is to use a special low-distortion band pass filter. Cryogenic filters [4] or special crystal filters [5] were tested to suppress the testing signal distortion. However, both these solutions are not easy applicable. In the first case it require special and expensive device, in the second case only a low amplitude signal can be applied. Therefore LC filters have been designed and tested using a special ferromagnetic material with a low non-linearity.

2 USED FILTERS AND ACHIEVED RESULTS

The Butterworth's approximation of the transfer function was used, because the attenuation characteristic of this type of filter is maximally flat [6]. Due to the fact that the filter was designed for the input and output impedance 50Ω , and relatively narrow band, the primary calculated values of components could not be practically applied. The Norton impedance transformation was used to transform this result to usable values. The bandpass filter of the 3rd order for the middle frequency of $f_m = 100$ kHz and the relative bandwidth of 0.05 is shown in the Fig. 1 as an example.

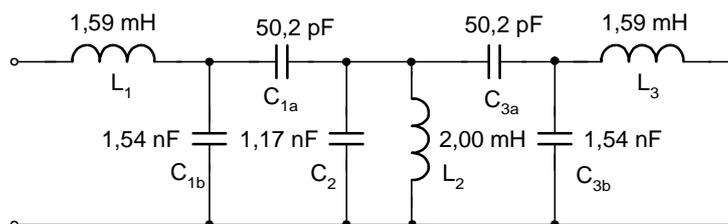


Figure 1. An example of the designed bandpass filter (for middle frequency 100 kHz)

realized with cores containing large air spaces that linearized consequential hysteresis curve. In Fig. 3, the scheme is linked to the bandpass of the 3rd order of the Butterworth's approximation, whose has a middle frequency of $f_m = 100$ MHz and a relative bandwidth of 0,05. In this case, the Norton's transformation is not used for achieving realizable ratios of value of the components (for the reason of non-realizably small values of the capacitors C_{1a} and C_{3a} - viz. Fig. 1), but rather so-called imittance invertors are used in the form of capacitor T-network. After the application of these invertors the consequential circuit is created only by serial resonant circuits in longitudinal branches and attaching capacitors in lateral branches. In this case the used coils are made without cores and are therefore linear. Even the distinctive resonant increase in individual parts of the circuit does not over-saturate the coils and the resulting distortion of the filter is negligible.

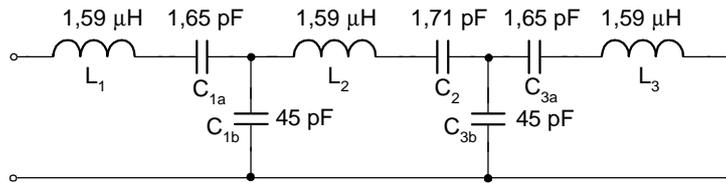


Figure 2. An example of designed bandpass filter (for middle frequency 100 MHz)

From the discussion mentioned above, it is obvious that using passive LC filters for the filtration of a signal for the purpose of gaining a spectrally clean sine wave signal is applicable for frequencies greater than several MHz. For lower frequencies, the distortion of the signal is influenced by the non-linearity of ferromagnetic material of the used coils. Since hysteresis curves of ferromagnetic materials are odd functions, distortion expresses the increase of odd harmonic components. All other components are suppressed enough. In the resulting signal there remains a small number of higher harmonic components. The obtained harmonic testing signal is suitable for the correction of the harmonic distortion with the help of method of the spectrum subtraction. It is based on the FFT test and its basic idea is the fact, that the Fourier Transform is a linear operation (see [1], [2]). Therefore it is possible to recognize spectral lines, which belong to the used generator, and the lines arising due to non-linearity of a tested ADC. The spectrum measured on the ADC output is corrected for the known spectrum of the testing signal, and the final spectrum corresponds to the non-linearity of the tested ADC. It makes possible to digitally correct the known distortion components.

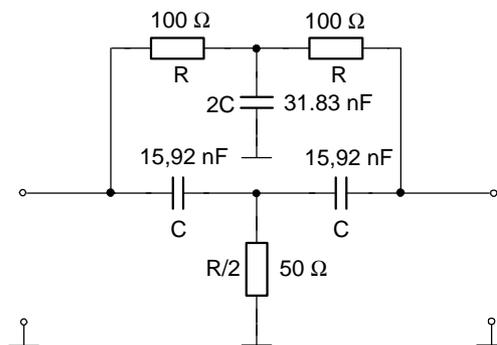


Figure 3. The notch filter for middle frequency 100 kHz

Because the dynamic range of the "reference" spectral analyzer (in this case VXI module HP E1430A) is restricted, it is important to evaluate the size of the greater harmonic amplitude. The desirable way is the elimination of the basic harmonic signal and to increase the gain input amplifier. Closer evaluation of the spectrum of the resulting signal, especially the size of the amplitude of its higher harmonic components is realized by a cascading connection LC bandpass (viz Fig. 1) and an RC bandstop (notch) filter, made by a form of parallel-T filter (Fig. 4). The advantage of such a notch is its practically insignificant distortion. The block diagram of the resulting measuring chain is in Fig. 5.

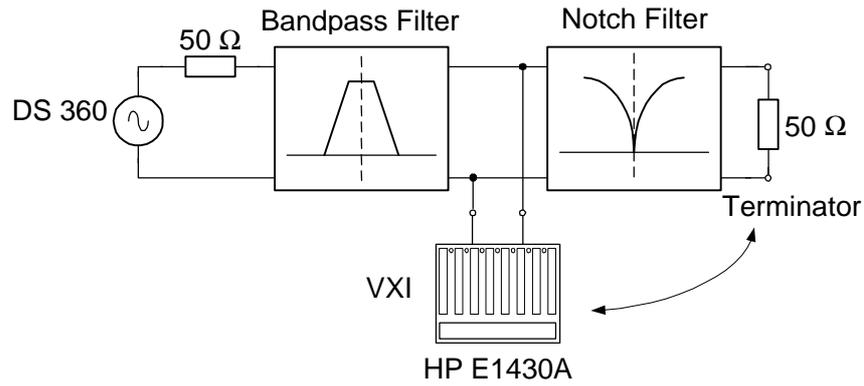


Figure 4. The block diagram of the measuring chain

The bandpass filter (terminating either a terminator $50\ \Omega$ or an VXI module, whose input impedance is $50\ \Omega$) is connected to the output of the generator. Then, the notch filter is connected to the output of bandpass filter, and its output is terminated in a similar way. Measurements are divided into two steps. In the first step, the output signal of the bandpass is measured using VXI module and the output of the notch filter is terminated by the terminator $50\ \Omega$. Measuring the actual testing signal, that is including non-suppressed basic harmonic component is executing in this case. In the second step, the output of a bandpass is terminated with $50\ \Omega$ terminator and the output signal of a notch is measured. In this case, the testing signal is measured with a distinctively suppressed basic harmonic and therefore with a greater resolution of higher spurious harmonics. There is an example of measured spectrum with a frequency of 100.995 kHz and an amplitude of 1.1 Vpp in Fig 6.

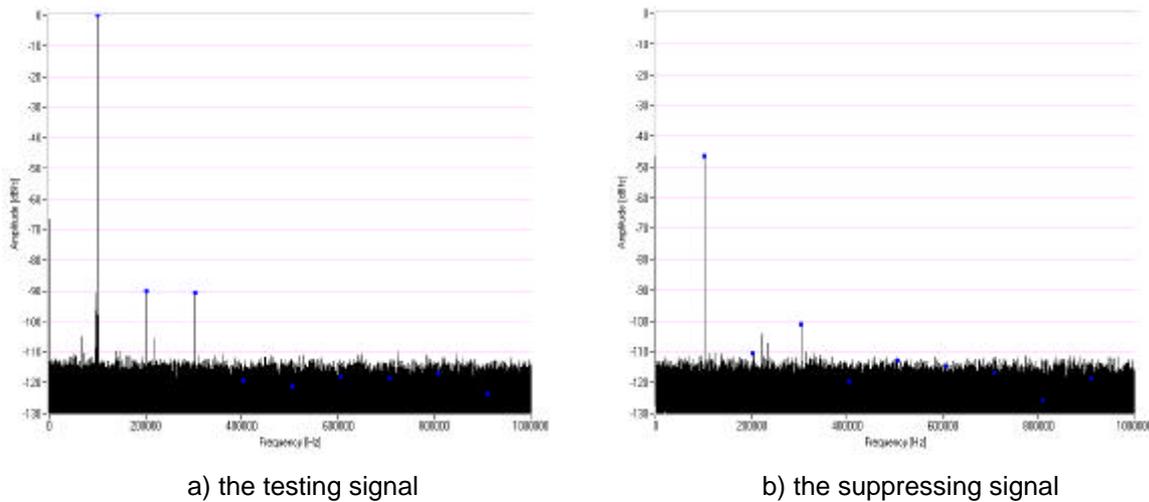


Figure 6. The resulting testing signal before and after notch filter

The sense of the measuring chain described above is to achieved the same conditions by generating of a testing signal even during measurement of its distortion. The measured results of the distortion are important to correct on the change of the amplitude frequency response under the influence of incorrect impedance matching of the bandpass. As is shown in Fig. 7 (a simulation by the PSPICE program) the shape of the amplitude frequency response of an "stop" band on the output of the bandstop filter is basically consistent with the shape of a characteristic on the output of the bandpass. However, under the influence of the incorrect impedance matching is more suppressed. Curve a) shows an amplitude frequency response of the bandpass with correct impedance matching, curve b) is the amplitude frequency response of the bandpass with incorrect termination and curve c) is the amplitude frequency response of the output of the notch.

To retain correct values of the amplitude of the spectrum it is important to correct measured amplitudes by this shift. Concretely, for the second, third and fifth harmonic components are values of correction approximately 14.6 dB, 9.7 dB and 5.4 dB.

Another important factor, influencing the results of the measuring is a distortion of the input amplifier of the VXI module used, especially the pertinent change of that distortion with the change of the gain of the input amplifier of the module.

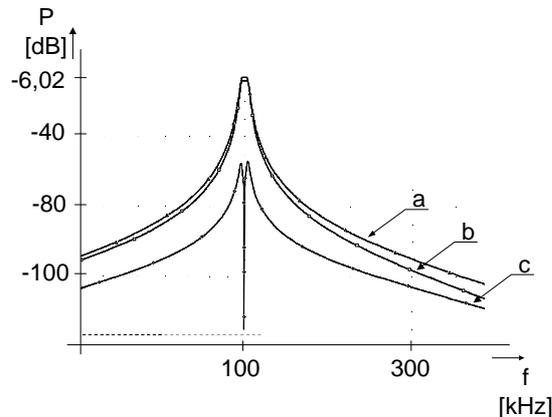


Figure 5. Amplitude frequency response of individual parts of measuring chain

3 CONCLUSION

The designed solution makes it possible to test the dynamical quality of middle resolution (12 - 16 bits) AD modules in frequency range from several tens of kHz (16-bits ADC) to several MHz (12 bits ADC) using commercial instruments. The first measurement for frequency 100 kHz confirmed that this method is applicable in practice. The filters (both bandpass and notch) are designed and built for the frequency range from 20 kHz to 200 kHz and for frequency 100 MHz (only bandpass). It enables to verify practically this method in this frequency range. It should be stated that for some special cases the results are not satisfying enough.

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