

Extension of the Test System for Middle-Resolution Digitisers up to 20 MHz

Vladimir Haasz, Jiri Kalina, Milan Komarek, David Slepicka, Petr Suchanek

Czech Technical University in Prague, Faculty of Electrical Engineering, Dept. of Measurement Technická 2, CZ-16627 Prague 6, Czech Republic; phone +420224352186, fax +420233339929; haasz@fel.cvut.cz

Abstract – The system for testing of digitisers at the frequency of input signal of 1 MHz designed and manufactured at the Dept. of Measurement in the last years was extended for the frequencies up to 20 MHz. Sets of common LC filters (both band pass and band stop) for frequencies 4.4, 9.5 and 19.5 MHz were developed. First experiments showed that these low-cost LC filters based on coils with ferromagnetic cores are sufficient for direct testing of digitisers with $ENOB < 14$ at a frequency of the test signal up to 10 MHz and for digitisers with $ENOB < 12$ up to 20 MHz.

I. Introduction

Most of the methods for ADC dynamic testing are based on a spectrally pure sine wave test signal. The basic assumption is that the distortion measured by a tested ADC is caused only by the ADC and not by the test signal or a signal path. This can be relatively easy fulfilled in a frequency range up to 100 kHz and ADCs with a resolution of 16 bits, because commercial low-distortion audio generators can produce test signals with sufficient quality.

Another situation is at higher frequencies, where the output signal from generators is very distorted by harmonic components resulting in low Total Harmonic Distortion (THD). Also non harmonic components described by the Signal to Non-Harmonic Ratio ($SNHR$) are present in their output signal. All these phenomena make such a generator unusable for middle or high resolution ADC testing. The measured frequency spectra of the output signal of generator Agilent 33120A for frequencies 4.4, 9.5, and 19.5 MHz are shown in Fig. 1 as an example, and the corresponding values of THD and $SNHR$ are presented in Table 1. Such a signal is sufficient only for testing of digitisers with $ENOB < 8$.

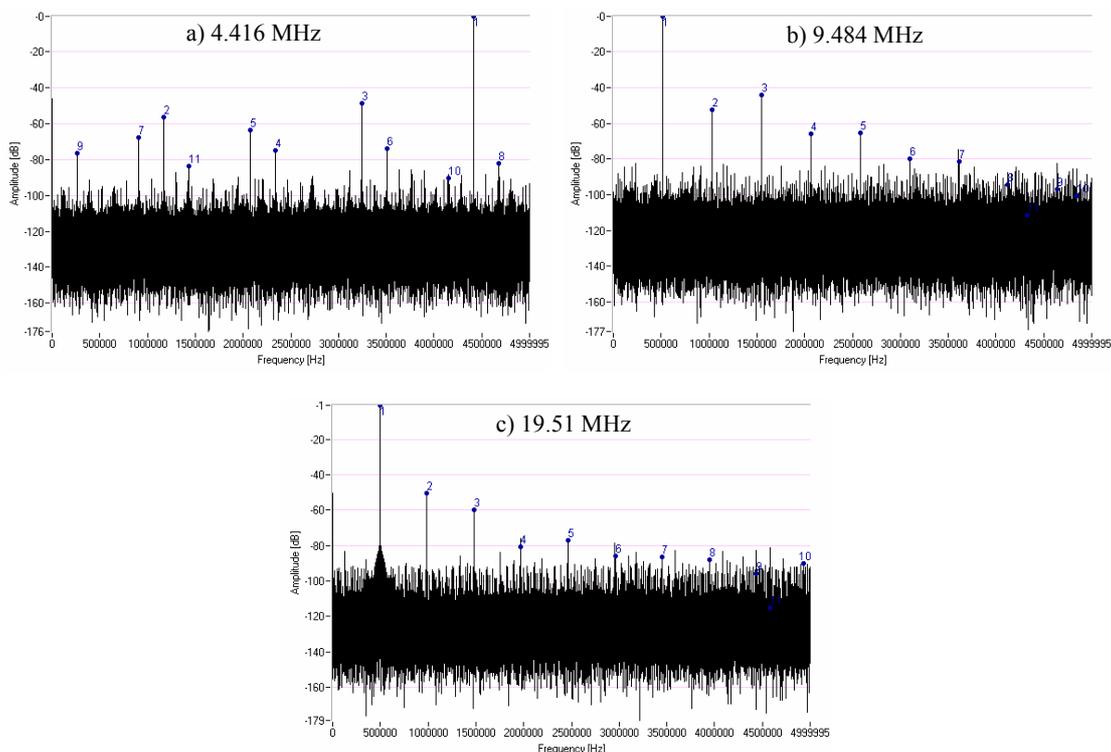


Fig. 1. Measured frequency spectra of output signal of generator

Table 1. Parameters of generator output signal (measured in dBc)

| | 4.4156 MHz | 9.4841 MHz | 19.508 MHz |
|-------------|------------|------------|------------|
| <i>THD</i> | -47 | -43 | -49 |
| <i>SNHR</i> | 63 | 56 | 57 |

One possibility how to improve the signal quality for the ADC testing is the filtering of a distorted signal. High-quality LC filters with a near-linear transfer characteristic are ideal for this purpose, though they are relatively expensive and sizable. Another way is to use common low-cost LC filters, which employ coils with ferromagnetic cores, and following digital correction of residual harmonic components. The system for testing of high-resolution digitisers at a frequency of 1 MHz was introduced in [1] and the characteristics of high-quality filters were published in [2]. Presented system enables to apply both ways mentioned above. All filters (both high-quality and common low-cost) were designed for the sixth order with capacitive coupled LC resonators (see [2] in detail). Good results were achieved using the system (see [3]) and initiated the extension of filter sets also for higher frequencies. The simpler realization and the fact that there are no digitizers with $ENOB > 12$ in frequency range of the input signal above 1 MHz at disposal at CTU-FEE now eventuates in development of low cost filters at first.

II. Extension of the system up to 20 MHz

The choice of the test signal frequency is based on the recommendation of IEEE Std 1241-2000 [4]; the optimal frequency f_{opt} should fulfil the condition of M equal spread phases in the range of 0 to 2π (M is the number of samples in a record). It is also important to satisfy the condition that the spectral lines of higher harmonic components, which mirror around a frequency of $f_s/2$ and 0, overlap with the spectral lines neither in the basic frequency band nor each other. Based on this analysis, the following frequencies were chosen: 4.4156 MHz, 9.48416 MHz and 19.5076 MHz. The structure of designed filter is the same as in the system of 1.053 MHz - see Fig. 2, but the component values were recalculated for new frequencies - see Table 2.

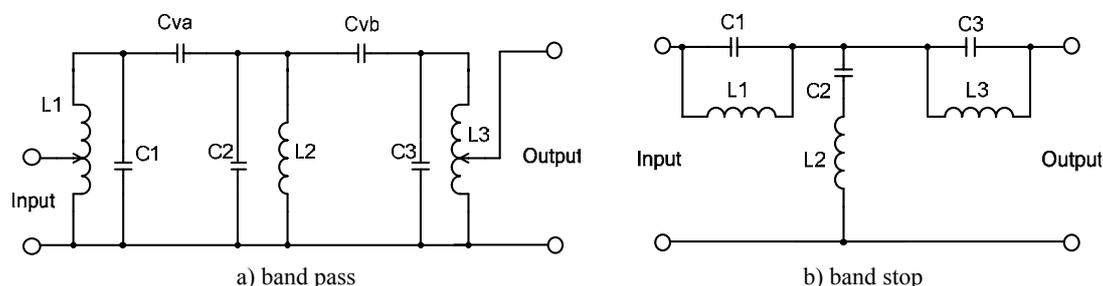


Fig. 2. Circuit diagrams of developed filters

Table 2. Component values of band pass and band stop filters

| Central frequency (MHz) | band pass filters | | | | | band stop filters | | | |
|-------------------------|-----------------------------------|-----------------|------------|-----------------------|-------------------|------------------------------|-----------------|------------|-------------------------|
| | L_1, L_2, L_3 (μH) | C_1, C_3 (pF) | C_2 (pF) | C_{va}, C_{vb} (pF) | Transformer ratio | L_1, L_3 (μH) | C_1, C_3 (pF) | C_2 (pF) | L_2 (μH) |
| 4.4156 | 50 | 25.5 | 25.0 | 0.5 | 37.3 | 1.86 | 699 | 827 | 1.57 |
| 9.4841 | 9 | 30.7 | 30.1 | 0.6 | 23.2 | 0.87 | 325 | 385 | 0.73 |
| 19.508 | 3 | 21.8 | 21.4 | 0.4 | 19.2 | 0.42 | 158 | 187 | 0.36 |

III. Achieved results

Signal quality on the band pass filter output was measured using a band stop filter (to decrease the signal dynamic range) and VXI HP E1430A digitiser (the demand on its linearity is not critical due to band stop filter application). To fulfil impedance matching, a terminator had to be inserted between the band pass and band stop filters – see Fig. 3.

Measured spectra (on the band-stop filter output) are displayed in Fig. 4 and the values of distortion recalculated on the band-pass filter output (the signal using for testing of digitisers) are shown in Table 3. These values enable to use such a signal for testing of middle resolution digitisers.

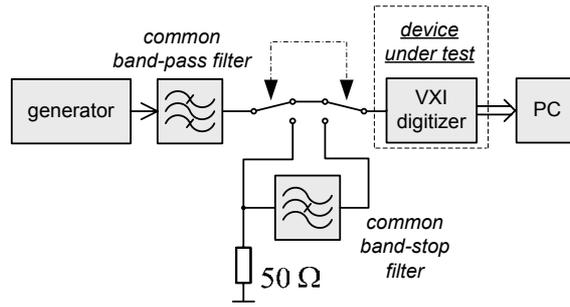


Fig. 3. Digitiser testing set-up

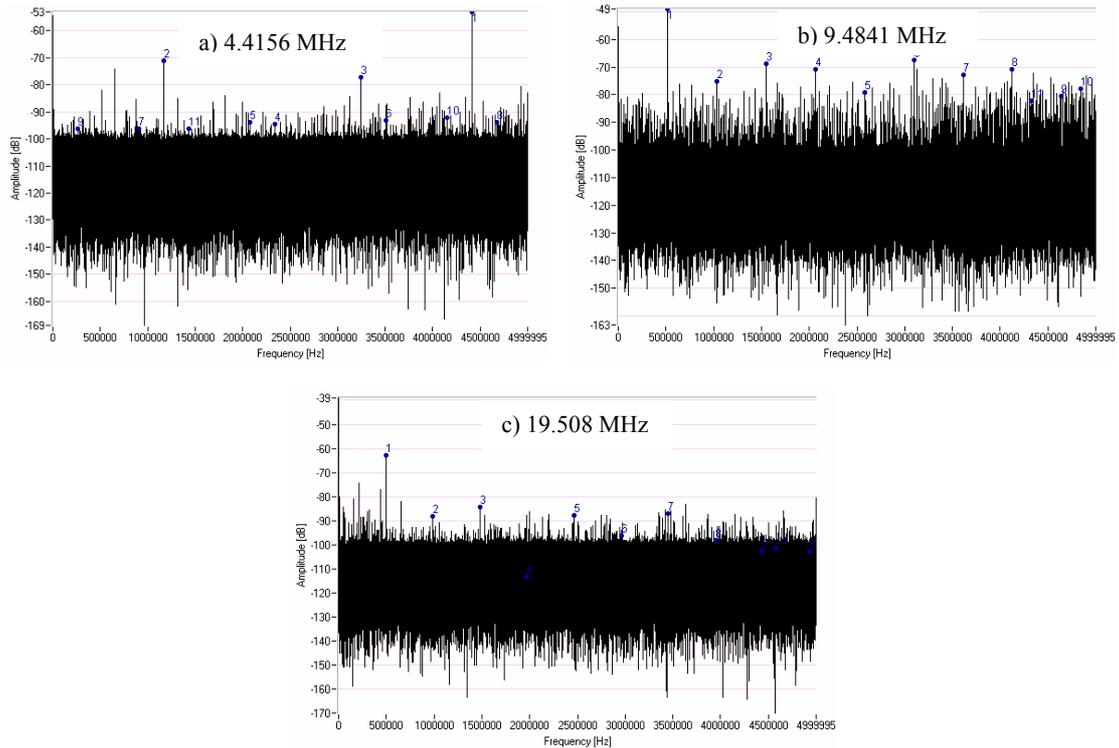


Fig. 4. Measured spectra on band-stop filter output

Table 3. Distortion recalculated to the band-pass filter output (measured in dBc)

| | 4.4156 MHz | 9.4841 MHz | 19.508 MHz |
|-------------|------------|------------|------------|
| <i>THD</i> | -91 | -90 | -104 |
| <i>SNHR</i> | 97 | 93 | 99 |

The VXI digitiser HP E1430A was used as a device under test to verify an applicability of the system. The test signals mentioned above with amplitude near input range of VXI digitiser were sampled with frequency 10 MHz. The spectra of digitised signal are shown in Fig. 5 and the calculated average values of *THD*, *SNHR* and *ENOB* are presented in Table 4 (it is necessary to mention, that the reproducibility of measurement was about ± 5 dB).

Table 4. Measured parameters of tested digitiser

| | 4.4156 MHz | 9.4841 MHz | 19.508 MHz |
|-------------|------------|------------|------------|
| <i>THD</i> | -82 | -75 | -62 |
| <i>SNHR</i> | 65 | 66 | 65 |
| <i>ENOB</i> | 10.5 | 10.5 | 9.7 |

Since the parameters of testing signals filtered by a band-pass filter are in all cases about 10 dB (or more) better than the values calculated from the digitised signal, their quality is sufficient and the results agree with the veritable parameters of the tested digitiser.

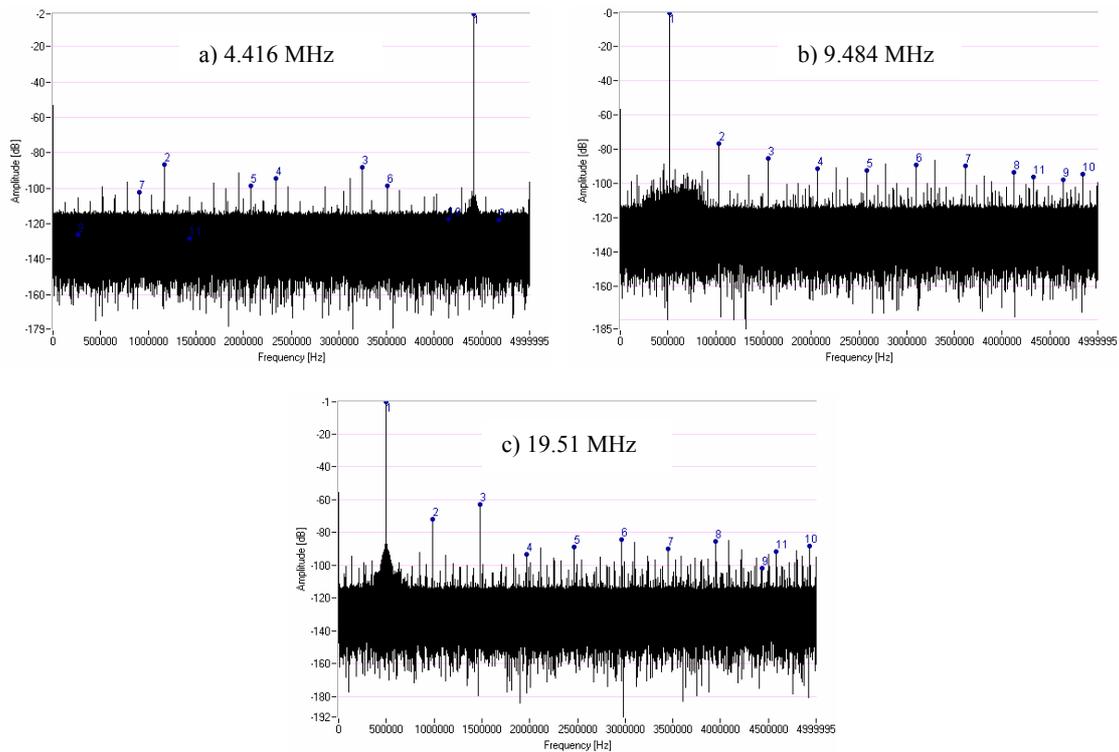


Fig. 5. Spectra calculated from digitised signal

IV. Conclusion

The system developed using common low-cost LC filters enables to measure dynamic parameters of middle resolution – high speed digitisers for input signal frequency up to 20 MHz. The experimental results verified that even such a system is sufficient for direct testing of digitisers with $ENOB < 14$ at the frequency of the test signal up to 10 MHz and $ENOB < 12$ at 20 MHz. In the case that a better digitiser should be tested the frequency spectrum correction method can be applied (see [1]).

The main disadvantage of the presented low-cost solution lies in worse reproducibility of measured results of test signal distortion (about ± 5 dB), than in the 1 MHz system mentioned in [3], where high-quality filters were used. This is probably caused by lower stability of parameters of filters and low quality of their shielding, because they are built inside cheap metal boxes designated for TV amplifiers and common used capacitors and coils were applied. Besides, all components of the system are connected by BNC connectors, which do not ensure as good connection as N-connectors used in the high quality filters presented in [2]. However, the price of presented solution is lower in order in comparison with high quality filters mentioned above and with the achieved parameters are sufficient for most commercial producing digitisers with input frequency range up to several tens of MHz.

References

- [1] Haasz, V. – Slepíčka, D.: *Frequency Spectrum Correction Test—Practical Experience*. Proceedings of IMEKO TC-4 Symposium. Athens, 2004, pp. 881–886.
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