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TRANSPORTABLE REFERENCE AD DEVICE – NEW INNOVATED VERSION

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Abstract - A transportable high stable reference AD device was designed and realised for a comparison of systems for testing a dynamic quality of ADCs or AD modules two years ago. In spite of the fact that several comparative measurements were successfully executed, some limitations and imperfections were found out. Therefore a new innovated version of the device was designed and developed based on existing experiences. The new solution is described in this paper.

Keywords: ADC testing, reference AD device

1. INTRODUCTION

A number of laboratories, which are interested in ADC testing, developed new methods and systems for it in the last several years. These are mostly based on well known IEEE Standards [1] or [2]. To assess the real precision of realised testing systems and to compare advantages and disadvantages of applied methods, the comparative measurements should be executed. To make it possible, a transportable high stable reference AD device was designed and built in the Dept. of Measurement of FEE – CTU in Prague in 2000 [3]. Its usability was investigated and proved by the comparison of the measurements made in the Laboratoire de micro-électronique IXL – University Bordeaux, in the laboratory of Institute of Microelectronics and Mechatronics Systems Ilmenau, and in the ADC T&M Laboratory of the Dept. of Measurement of FEE CTU in Prague [4]. However, some limitations and imperfections were found out during these measurements. Therefore the new innovated version of the transportable reference AD device was designed and developed.

2. INNOVATED VERSION OF TRANSPORTABLE REFERENCE AD DEVICE

The new version should increase the functionality and the universality of the device and eliminate some imperfections of the first version. The following modifications were executed:

- internal shielding case was modified in the way it would enable an easy replacement of input modules
- new design of the control part takes into account different interfaces and timing of various types of ADCs; this makes it possible to apply several types of ADCs
- timing circuit was modified to enable an easy application of a coherent sampling
- control part was optimised with regards to minimum disturbance
- testing data generator was added to the control part to be possible to test the transmission way
- power supply (including batteries) was placed into a separate box.

2.1. Hardware structure

The input module is (same as in the first version) full galvanic insulated and it is placed in an internal shielding case that is thermostated. The module is based on the professionally developed AD modules. The AD modules with the following types of ADCs are at disposal:

- 14-bits cascade ADC AD9240; 10 MSa/s;
- 16-bits sigma delta ADC AD7723; 1,2 MSa/s;
- 16-bits successive approximation ADC AD976A (AD977A); 200 kSa/s.

Concerning the control and data transfer module (see Fig. 1), the microcontroller of the clone 51 was applied also in the new version, but the fast part and the data memory was changed. The new concept of the fast part is based on a FPGA circuit. It executes all tasks, which pursued pristinely the simple fast digital circuits in the first version. Besides, it makes it possible to reconfigure the data input and the timing according to the used ADC, to realise the testing data generator etc. Further, the FIFO data memory was replaced by the fast SRAM with the capacity 256 kSa. It enables on the one hand massively enlarge the amount of off-line transferred data, on the other hand to record (in co-operation with FPGA) a numerousness of code words for statistical tests in the real time.

The supply part provides (same as in the first version) the battery power supply for galvanic insulated part during precise measurement, charging of batteries, and a net power supply for a digital part of the device. It enables also to supply the whole device during a measurement preparation or for a verification of correct operation of the device to save batteries. The charging of batteries could be active contemporary in this case. However, the supply part was separated in two sections in the new version. The own power supply (net transformers, charging circuits and

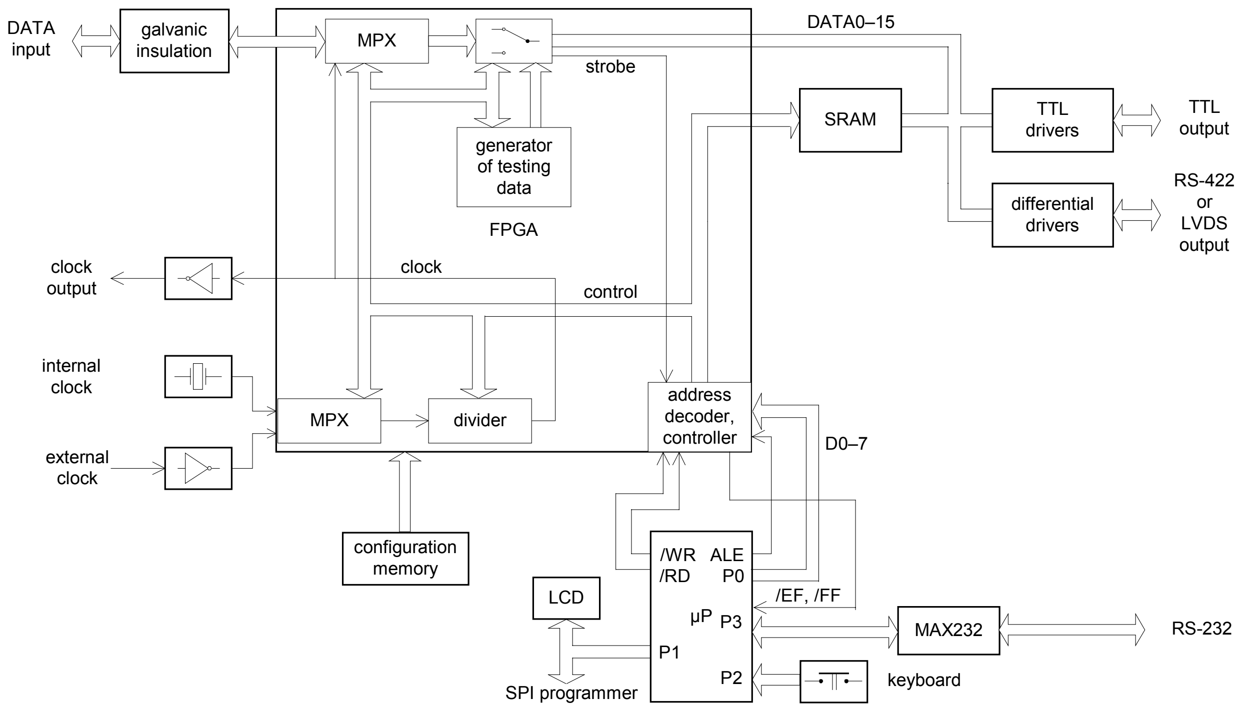


Fig. 1. The innovated control and data transfer module

batteries) was optimised and it was placed in a separate case, while stabilisers are placed near the supplied circuits in the main case. The minimum operating time without charging is about 3 hours, the charging time 1 hour. Both the charging and the fall under the minimum operating voltages of the batteries are indicated by LEDs.

2.2. Embedded and user software

The whole device is controlled by means of microcontroller using a keyboard at the front panel, a serial link RS-232 or a LVDS or a TTL interface. The menu structure is presented in the Fig. 2. Besides, the operating temperature of the AD module is displayed and its value can be set. A relevant LED indicates an attainment of the set temperature. The build-in buzzer indicates a correct press of a bottom or it signalises an operating event (start of the data acquisition etc.)

All settings are saved in the internal EEPROM, even if the device is switched off. The block diagram of the embedded software is presented in the Fig. 3.

The integral part of the device is also a user software, which runs in the host computer. Based on a good experience with the software package Digitiser [5], a modified version of it was created. The new version (DS 1.5) enables to control both the first and the new version of the AD transfer standard, and to process the measured data. The windows structure makes it possible:

a) to verify a correct connection and a setting of parameters (a bottom *Test* in the main window – see Fig. 4);
b) to set the version of connected device (a switch *ADTS* or *ADTS2*)
c) to set the parameters of used device (a bottom *Preferences* – it open a special window – see below)
d) to start the measurement (a bottom *Start*)
e) to process automatically the measured data and to calculate *ENOB* and *SINAD* (an item *Count*); the detailed specification can be made using items ... *Panel*

The window *Preferences* (Fig. 5) enables to set all change able parameters of connected device (bookmarks *ADTS* or *ADTS 2*). The window is divided into two parts in this case – the first one is designed for a setting of a data source and the data output (*Output settings*), the second one for a clock and trigger setting (*Clock*). The other bookmarks concern the date transfer (*Serial*), the generators' settings for GPIB interface control (*Generator*), the software signal generation (*Simulation*), the general ADC settings like resolution etc. (*Board*) and basic acquisition settings like number of samples etc. (*Acquisition*) [5].

3. MEASURED RESULTS

3.1. AD module with ADC AD977A (max. 200 kSa/s)

The first comparable measurements using the new AD transfer standard ADTS2 with the AD module with AD977A evaluation board were executed in the ADC T&M Laboratory, Dept. of Measurement of FEE CTU in Prague, and in the laboratory Messeinrichtung für Analog-Digital-Umsetzer of Physikalisch-Technische Bundesanstalt Berlin (October 2002). The results of FFT test (*SINAD*, *THD* and *SNR*) using 128 kSa are shown in Table I together with the values measured using the first version (ADTS1). The typical spectra measured using the both versions of ADTS in Berlin and Prague are shown in the Fig. 6 and Fig. 7.

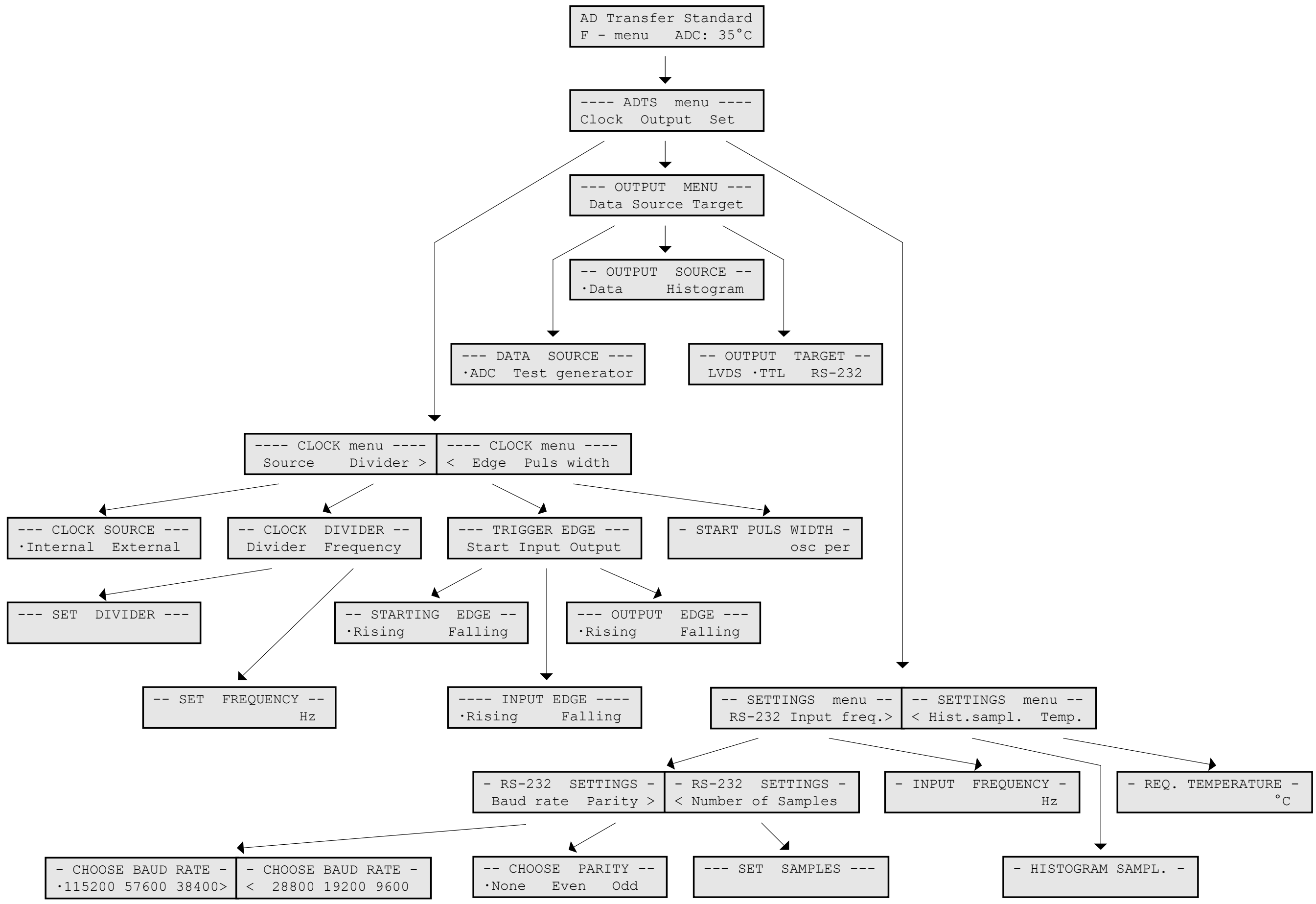


Fig. 2. The menu structure

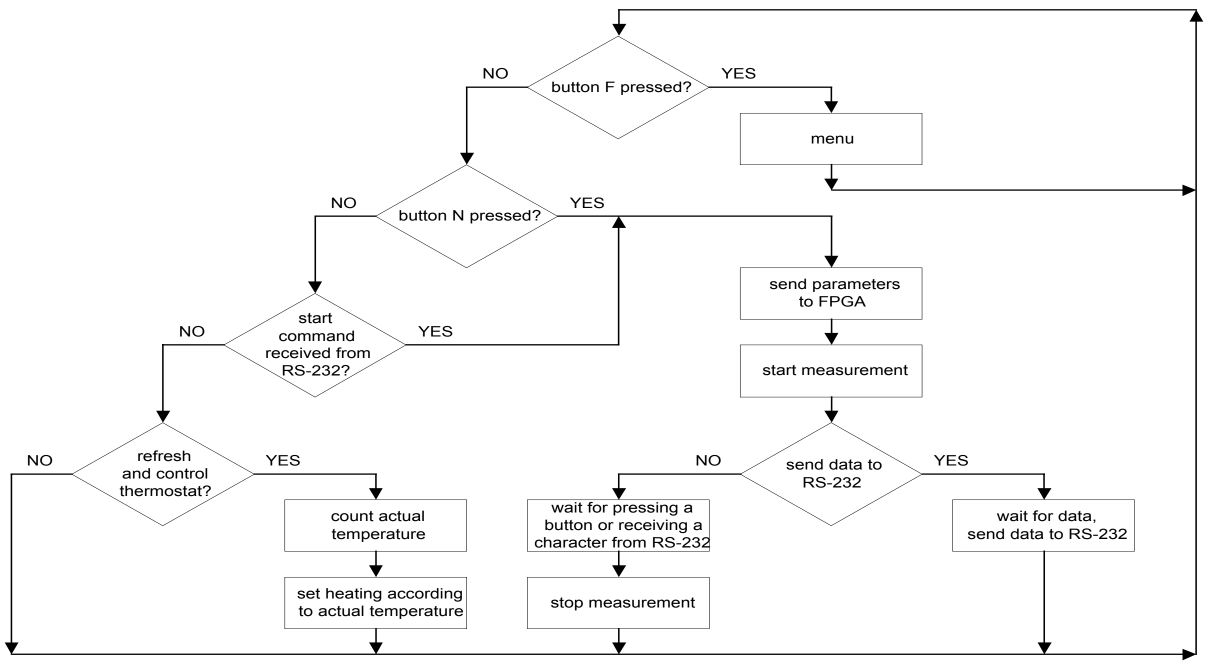


Fig. 3. The block diagram of the embedded software

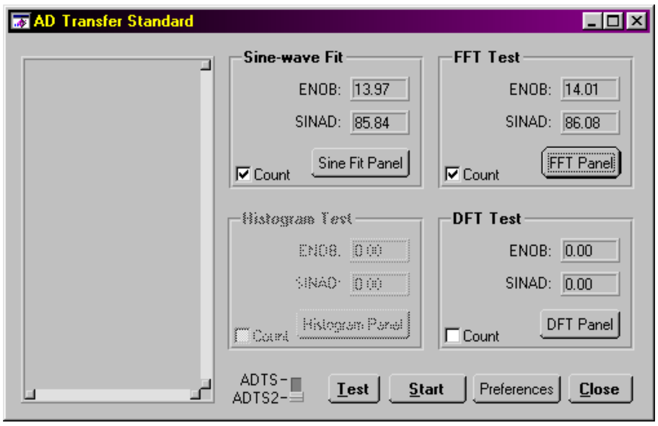


Fig. 4. The main window

As follows, all measured values for frequencies up to 20 kHz are almost the same (with difference mostly bellow 2 dB only); for higher frequencies, the quality of each generator is more visible.

Generator AP suffers from the frequency instability and it causes enlarging of the spectral line of the first harmonic. Because, the standard algorithm includes only a few bins around the biggest spectral line to the signal, the other bins are considered as a noise and consequently *SNR* is therefore decreased. However, *THD* of this generator appears to be very good on the other hand.

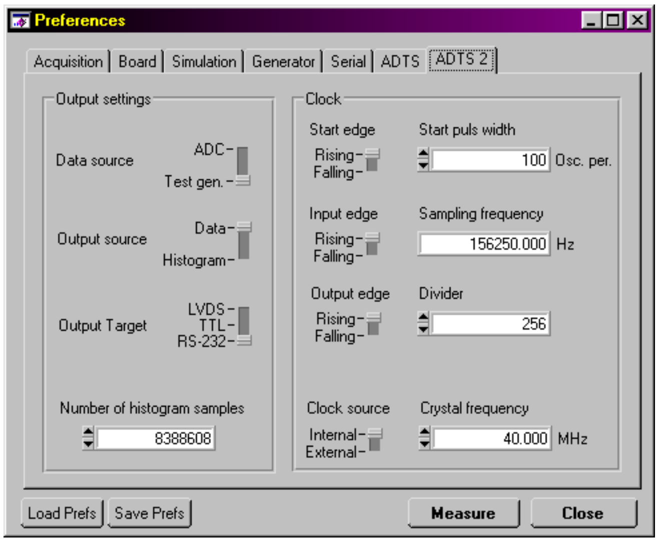


Fig. 5. The window "Preferences"

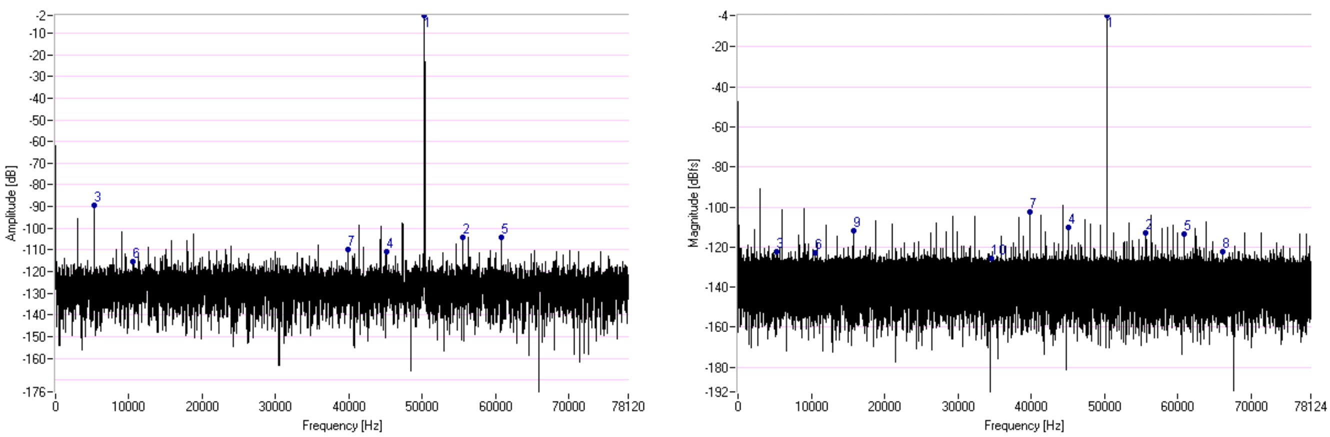
3.2. *The first experiments with 14-bit AD module AD9240 (10 MSa/s)*

The AD module with 14 bit ADC and sampling rate 10 MSa/s was also built-in and tested. There was a certain problem concerning the basic level of noise (the noise floor for the terminated input was 67 dB). It was probably caused by the noise of the voltage reference. Reduction of this noise will be the subject of further investigation.

Table I. Values of *SINAD*, *THD* and *SNR* measured in Prague (DS 360) and Berlin (AudioPrecision System II) using the both AD transfer standards and applying the FFT test for 128 kSa.

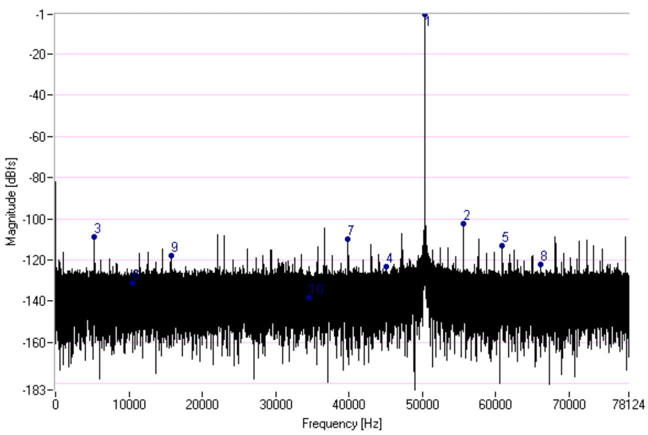
frequency of input signal (kHz)	***SINAD* (dB)**				***THD* (dB)**				***SNR* (dB)**			
	DS 360		AP Syst.II		DS 360		AP Syst.II		DS 360		AP Syst.II	
	ADTS1	ADTS2	ADTS1	ADTS2	ADTS1	ADTS2	ADTS1	ADTS2	ADTS1	ADTS2	ADTS1	ADTS2
10.333	86	86	86	86	-99	-103	-101	-102	86	86	86	86
20.333	86	86	85	85	-102	-101	-101	-104	86	86	85	85
50.333	83	84	79	79	-86	-96	-99	-100	85	84	79	79
100.333	78	81		75	-79	-90		-93	83	82		75

Remark: Values of *THD* was calculated from the first 10 harmonic components; relevant harmonic components displayed mirrored are also included.

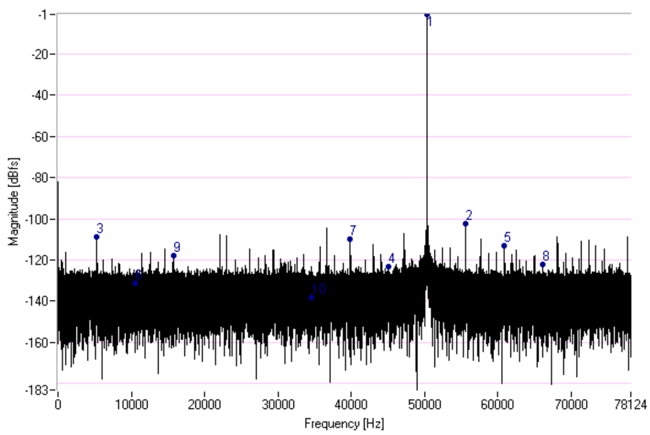


a) ADTS1 b) ADTS2

Fig. 6. The measured frequency spectrum of an input signal with frequency f_{in} = 50.333 kHz, generator DS 360 (Prague)



b) ADTS1



b) ADTS2

Fig. 7. The measured frequency spectrum of an input signal with frequency f_{in} = 50.333 kHz, the generator AP System II (Berlin)

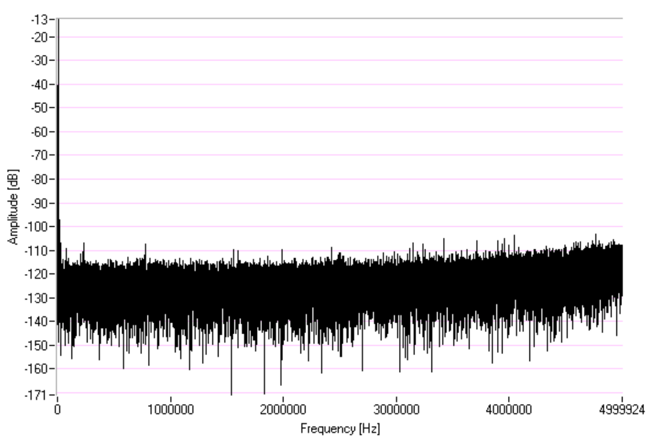
Since there is no commercial low-distortion generator with a frequency range up to several MHz suitable for 14 bit ADC testing, the generators SR DS360 and HP33120A were used for the first experiments. Both of them use a principle of a direct frequency synthesis. The first one is the low-distortion low-frequency generator fit for ADC testing (see above), however with the frequency range up to 200 kHz only. The second one generates the sinewave with frequency up to 15 MHz, but a distortion of the output signal (arisen due to a low resolution of an output DAC and only a standard low-pass filter) is too high.

The results of the first experiments are summarised in the Table II. It confirmed that the main problem of this AD module is its own noise. It should be solved in the near future. However, also in this case it is necessary to take into account, that the device is intended for a comparison of testing systems and not for an absolute measurement. For instance, a comparison of some properties of testing signal generators can be made from the frequency spectra presented in the Fig. 8, 9 and 10. The non-coherent sampling, the 7th order B&H window and a sampling rate 10 MSa/s was used in this case.

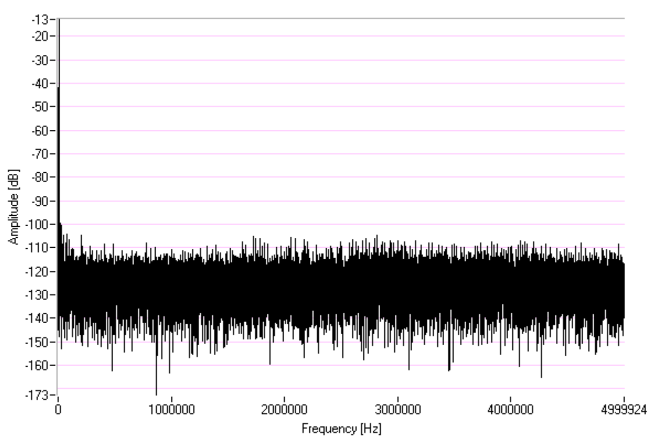
There is no antialiasing filter used in the applied AD module. It corresponds to the frequency spectrum by using the low-distortion generator SR DS360 (see Fig. 8a), where the rise of noise for the high frequency range was found. It corresponds to the former measurements [6], which showed significant spurious high-frequency components in the output signal for this type of low-distortion generators. Since the generator itself has a low harmonic distortion [7], the measured values of *THD* evidently correspond to the quality of this parameter of the AD module. On the contrary, the amount of higher harmonic components increases evidently with frequency of the output signal for the generator HP 33120A.

Table II. Measured values of *THD* (for the first 7 harmonic components) and *SNR* for generators SR DS360 and HP 33120A

freq. of inp. signal (kHz)	***THD*** **(dB)**		***SNR*** **(dB)**	
	SR DS360	HP 33120A	SR DS360	HP 33120A
10.333	-83,86	-83,33	63,49	65,26
20.333	-83,66	-80,02	63,41	64,78
50.333	-83,11	-73,98	63,38	64,34
100.33	-82,65	-69,04	63,07	64,13
197.77	-80,05	-63,28	63,15	63,54
500.33	-	-59,80	-	64,17
1333.3	-	-52,37	-	64,76

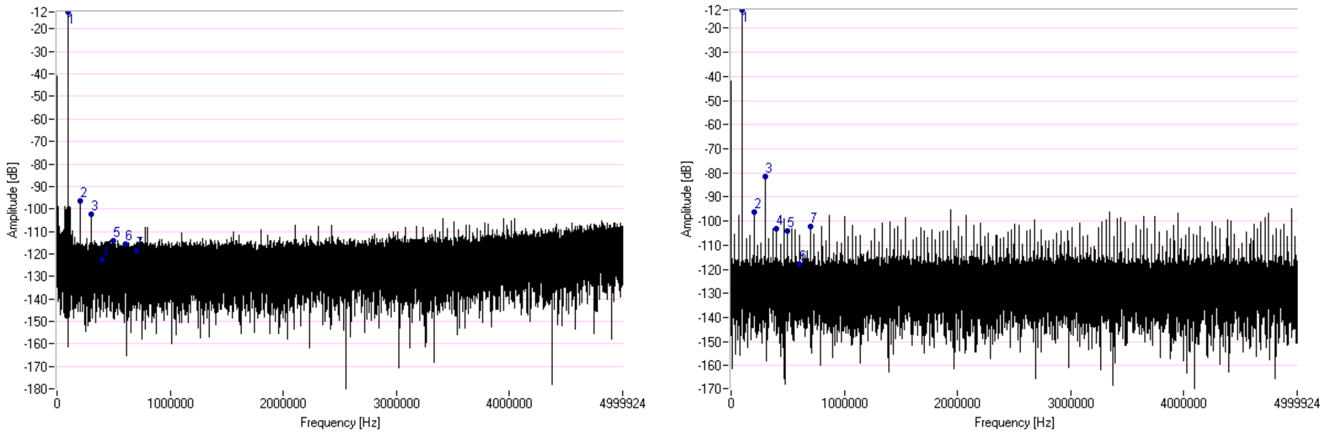


a) Generator DS 360



b) Generator HP 33120A

Fig. 8. Measured frequency spectrum of input signal with frequency f_{in} = 10.333 kHz



a) Generator DS 360 b) Generator HP 33120A

Fig. 9. Measured frequency spectrum of input signal with frequency f_{in} = 100.33 kHz

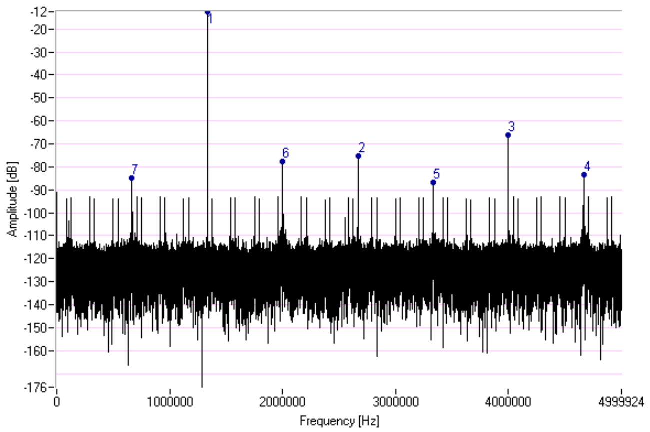


Fig. 10. Measured frequency spectrum of input signal with frequency f_{in} = 1 333.3 kHz; generator HP 33120A

However, the values of *SNR* were found nearly the same for all frequencies of the testing signal and for the both of generators. It confirms a high level of the basic noise mentioned above.

3. CONCLUSION

The new innovated version of the AD transfer standard was designed and developed based on the experience acquired during the measurements executed with the first prototype. Realisation of the new version was finished and its applications proved following advantages in comparison with the first prototype:

a) internal memory 256 kSa enables to execute the standard FFT and SWCF (*sine wave curve fit*) tests with sufficient resolution without on-line data transfer into a PC;

b) new construction – two separate cases of lower dimensions enable an easier transport;

c) changeable AD modules make it possible to enlarge a frequency range.

The first comparative measurement in PTB Berlin using 16-bit & 200 kSa/s AD module proved the advantages mentioned above. Further experiments will be pointed to the evaluation of the 16-bit & 1,6 MSa/s AD module using a Σ−Δ ADC. Concerning the 14-bit & 10 MSa/s AD module, laboratories with a testing signal generator reaching a sufficient quality will be searched in the next future to be possible to execute some comparative measurements using the testing signal in a several MHz range.

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