XVI IMEKO World Congress
Measurement - Supports Science - Improves Technology - Protects Environment ... and Provides Employment - Now and in the Future
Vienna, AUSTRIA, 2000, September 25-28

SYSTEM FOR DYNAMIC TESTING OF ANALOG TO DIGITAL MODULES

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Abstract: An automated system for dynamic testing of ISA, PCI and VXI modules in frequency range up to 1 MHz developed at Department of Measurement of FEE CTU Prague is presented. The application of the Hewlett-Packard E1430A high precision VXIbus digitizer for evaluation of testing signals is described.
Keywords: AD modules dynamic testing, test system, VXI bus

1 INTRODUCTION

Dynamic measurements of analog signals are usually performed using digitizers at present. The digitizers are produced not only as stand-alone instruments (digital oscilloscopes, waveform recorders), but also as modules with standard interfaces (VME and VXI modules, PCI and ISA plug-in boards, etc.). Applications of digitizers for precision dynamic measurements of non-harmonic signals require detailed knowledge of technical parameters describing their static and especially dynamic behavior. It was main reason for building of a specialized laboratory focused mainly on dynamic testing of high precision A/D plug-in boards and VXIbus modules at our department.

2 APPLIED METHODS

Methodology of testing is based on the IEEE Std. 1057-1994 [1] and IEEE-Std. 1241-Draft [2]. Basic methods using a high purity sine wave source are applied – the FFT spectrum analysis, the sine wave curve fitting and the histogram test. These methods provide all important dynamic characteristics including the frequency spectrum, the total harmonic distortion THD, the signal-to-noise ratio SNR, the signal-to-noise plus distortion ratio SINAD, the effective number of bits ENOB, the spurious free dynamic range SFDR and the differential and integral nonlinearity DNL, INL. Following algorithms are implemented for data analysis in our application software:

a) spectrum analysis:
   - FFT test for both the coherent and incoherent sampling [3]
   - DFT algorithm to avoid leakage effect by the incoherent sampling [4]
b) time domain analysis: the four parameter sine wave curve fit algorithm using matrix operations according to [1], clause 4.1.3.3.
c) histogram method using a sine wave testing signal
d) method of error spectrum generator correction [5]

3 TEST SYSTEM

3.1 Instrumentation and hardware

The basic test system consists of a PC and the ultra-low distortion synthesized generator (Stanford Research System DS-360) controlled via the IEEE 488 bus. The extended system includes a C-size VXIbus system controlled either by the RadiSys RADE PC7B embedded computer or by an external personal computer via the IEEE 1394 serial bus (the HP E8491A is used as a controller with VXI Resource Manager and Slot 0 capability). The VXI system contains the HP E1430A digitizer determined for evaluation of testing signals and/or the HP E1445A arbitrary function generator.

Following instruments can expand the measuring system:

- arbitrary/function generator for generation of a sine wave signal in the frequency range up to 1 MHz (Hewlett Packard 33120A);
- precision FFT spectrum analyzer (Hewlett Packard 35670A dynamic signal analyzer) determined for spectrum analysis of testing signals in the frequency range of 0.2 Hz to 102.4 kHz;
- heterodyne spectrum analyzer for measurement in the frequency range of 10 kHz to 3 GHz (e.g. ADVANTEST R3132);
- precision frequency counter (Stanford Research SR620) for short-term stability measurement;
- ultra-low distortion oscillator (Krohn Hite 4400A) - only manually controlled;

- set of band-pass passive filters used for improvement spectral properties of testing signal;
- set of passive notch filters used for evaluation of spectral purity of sine wave signals.

Amplitude characteristics of filters are measured using a measurement set-up shown in Fig. 1.

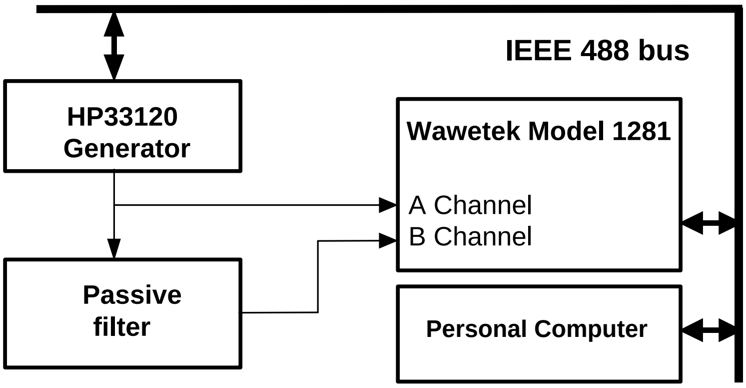

Figure 1. Test set-up for passive filter measurements

3.2 Application software

The application software, fully developed at our department, provides a complete environment for test control, data acquisition, analysis and graphical presentation of measured and processed data (see Fig. 2). It has been written in C language under the Windows95/98/NT operating system. Large troubles have occurred in programming of the HP E1430 digitizer. Since the producer does not support this VXI instrument under Win32, it was necessary to modify original C library and apply the Win32 HP SICL (Standard Instrument Control Library) for I/O communication with the digitizer. At present this software is applied as a DLL (Dynamic Link Library).

4 USE OF TEST SYSTEM

The described test system makes it possible to investigate the dynamic performance of PCI and ISA plug-in boards, VXIbus A/D modules, digital oscilloscopes and IEEE 488 digitizers with resolution up to 16 bits in the frequency range of 10 Hz to 100 kHz. The frequency range of testing is given by the spectral quality of the generator used.

4.1 Requirements on testing generator

The basic problem of dynamic testing is associated with a source of test signal. The harmonic signal is commonly used for high-resolution digitizers testing. In this case the sine wave signal must reach extremely low noise and distortion (e.g. high value of SINAD). SINAD of the signal should be better than SNR of an ideal N-bit converter defined as SNR = 6.02N + 1.76 (in dB). In the case when the spectral purity of signal is insufficient, it is absolutely necessary to apply passive band-pass low-distortion filters to eliminate higher harmonics and noise from the generator. Development of these filters is under way at our department at present.

4.2 Evaluation of HP E1430A digitizer

The HP E1430A digitizer is a C-size, register based VXIbus module with 23-bit ADC (see [6], [7]). The producer warrants these basic dynamic parameters [8]:

- sample rate: 10 MSa/s; output sample rate F_{S_OUT} can be reduced using digital decimation: $F_{S\_OUT} = F_S/2^{TDL}$, where F_S=10 MSa/s, TDL is the total decimation level (an integer number from 0 to 24);
- memory: 8 MB (2 MSa);
- dynamic resolution: from 11.0 to 18.00 “equivalent” bits depending on used bandwidth (see [7], pp. 1-2);
- noise density: -136 dBfs/Hz for effective sample rate bigger than 100 kSa/s and -134 dBfs/Hz for sample rate at range of 9.77 kSa/s to 78.125 kSa/s (at input ranges 62.5 mV and higher).;
- harmonic distortion: < -80 dBc or < –110 dBfs (see Fig. 2)
- spurious components: < -110 dBfs (when anti-aliasing filter on)

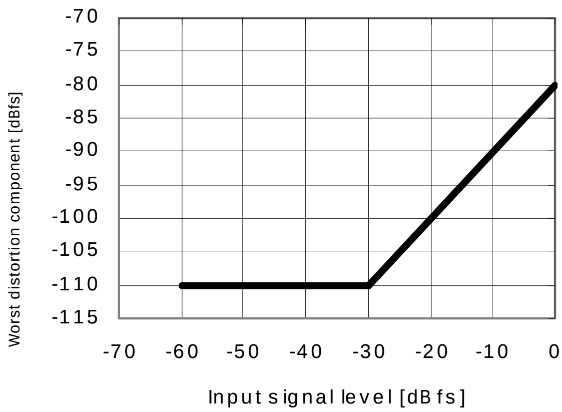

Figure 2. Distortion vs. input signal level

Following measurements were performed:

a) measurements of a noise and spurious components; determination of equivalent bits and the dynamic range;
b) measurements of the amplitude spectrum using a full scale testing signal at selected frequencies; determination of the harmonic distortion, SINAD and ENOB
c) THD measurements of sine wave generators by means of notch filters; comparison with results acquired by FFT and heterodyne spectrum analyzers.

Noise measurement. Measured noise parameters correspond with values guaranteed by the producer (see [8]). The measurement was performed with 50 Ω resistor at input connector; the antialias filter was activated. The typical example of the noise spectrum of E1430A digitizer is shown in Fig. 3. The results of equivalent bits measurement are presented in Tab. 1.

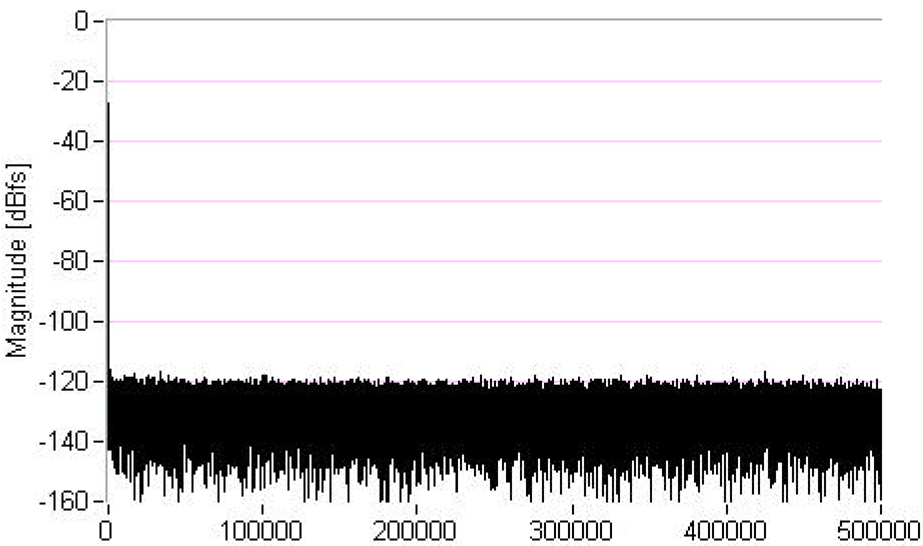

Figure 3. Noise spectrum of E1430A ADC module - input terminated with 50 Ω; (input range +/-1 V_{pk}, 131072 samples, effective sample rate 1.250 MSa/s, decimation level 3, DC coupling, antialias filter on)

Table 1. Comparison of equivalent bits (published in [7] and really measured) and measured ENOB; (input range +/- 1V_{pk}, 131072 samples; DC coupling, antialias filter on)

Total Decimation Level	0	1	2	3	4	5
Sample Rate [kSa/s]	10000.0	5000.0	2500.0	1250.0	625.0	312.5
Bandwidth [kHz]	4000.0	2000.0	1000.0	500.0	250.0	125.0
Equivalent Bits, see [7]	11.3	11.8	12.3	12.8	13.3	13.8
Measured Eq. Bits	**11.4**	**12.0**	**12.5**	**13.0**	**13.5**	**13.9**
Measured ENOB			**11.6**[1]	**12.3**[2]		**13.4**[3]

Note: ENOB was measured at frequencies [1]193.5 kHz, [2] 99.2 kHz and [3]20.52 kHz, respectively.

Measurement using full-scale signal. The DS 360 generator was used in the frequency range of 1 kHz to 200 kHz. Magnitudes of higher harmonic components caused by digitizer are guaranteed under -80 dBc. Typical values of ENOB at frequencies 193.5 kHz, 99.2 kHz and 20.52 kHz are presented in Tab. 1. The example of the spectrum of full-scale sine wave signal at frequency 20.52 kHz is shown in Fig. 4.

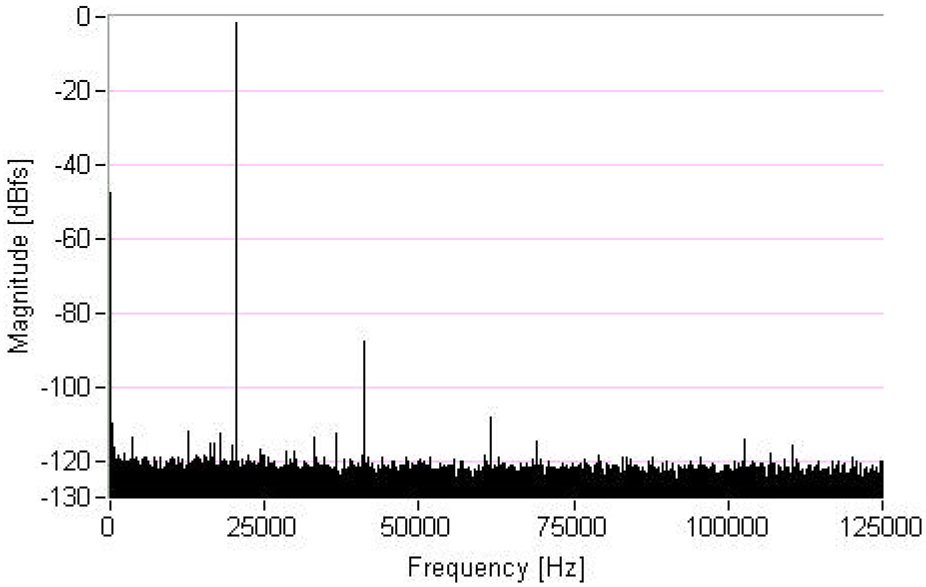

Figure 4. Spectrum of full scale sine wave signal (f_{sig} = 20.52 kHz) sampled by E1430A (input range +/- 1V_{pk}, DC,131072 samples, effective sample rate 312.5 kSa/s; antialias filter on)

4.3 Precise THD measurements of testing generators

The distortion of the HP E1430A digitizer corrupts results of the direct THD measurements of spectrally pure generators. For that reason precise distortion measurements are performed using the fundamental-suppression method, where the measured signal passes through a non-distorting notch filter that suppresses a fundamental harmonic component of the signal. In case of the –30 dB rejection, the dynamic range of the digitizer can reach 110 dB (see Fig. 2). Basic measurements of DS360 generator have been done at the frequency 20.52 kHz using the HP E1430A digitizer and the HP 35670A FFT analyzer. The results are published in [9]. Next measurements have been performed at frequencies 99.2 kHz and 193.5 kHz using the HP E1430A digitizer and the ADVANTEST R3132 spectrum analyzer. The results are shown in Tab. 2 and in Fig. 5, 6 and 7.

Table 2. Results of DS360 distortion measurement (after filter correction)

	f_{in} = 99.2 kHz			f_{in} = 193.5 kHz		
	HP E1430A		ADVANTEST	HP E1430A		ADVANTEST
Harmonic	without filter [dBc]	with filter [dBc]	with filter [dBc]	without filter [dBc]	with filter [dBc]	with filter [dBc]
2nd	-90.9	-93.0	-93.3	-86.0	-85.0	-85.8
3rd	-90.3	-92.5	-92.8	-78.8	-83.1	-83.2
4th	-116.9	x	x	-105.0	-110.3	x
5th	-100.6	-105.0	-105.2	-93.9	-101.2	x
THD[dB]	-87.4	-89.6	-89.9	-77.9	-80.9	-81.3

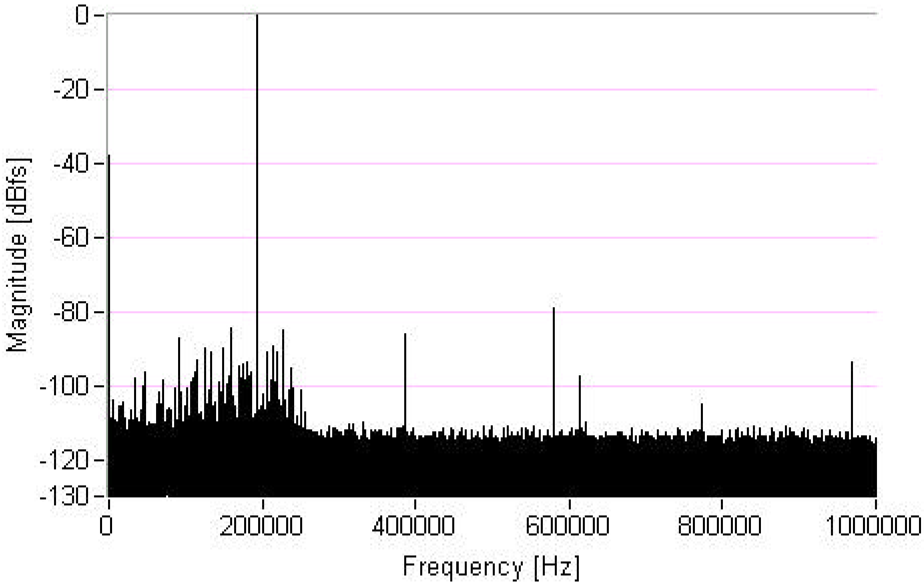

Figure 5. Spectrum of full scale sine wave signal (+/- 1 $V_{pk,}$ 193.5 kHz) – sampled by E1430A digitizer (input range +/- 1V_{pk}, DC, 131072 samples, effective sample rate 2.5 MSa/s; antialias filter on)

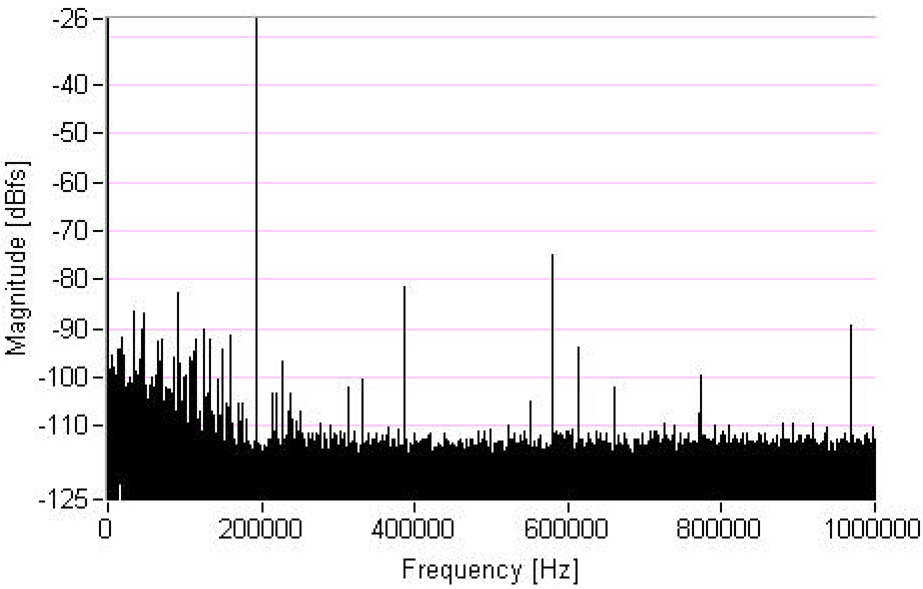

Figure 6. Spectrum of sine wave signal (+/- 1 $V_{pk,}$ 193.5 kHz) - measured with notch filter; sampled by E1430A (input range +/- 0.125 V_{pk}, DC,131072 samples, effective sample rate 2.5 MSa/s; antialias filter on)

5 CONCLUSION

The measurements proved very good dynamic quality of the E1430A digitizer, which can be used as a FFT spectrum analyzer appropriate for evaluation of low-distortion generators in the frequency range up to 4 MHz. The digitizer is sharply better than conventional FFT and heterodyne spectrum analyzers in key parameters as the dynamic range (SFDR >110 dB excluding distortion) and the frequency resolution (thanks to a large number of samples - up to 2 MSa).

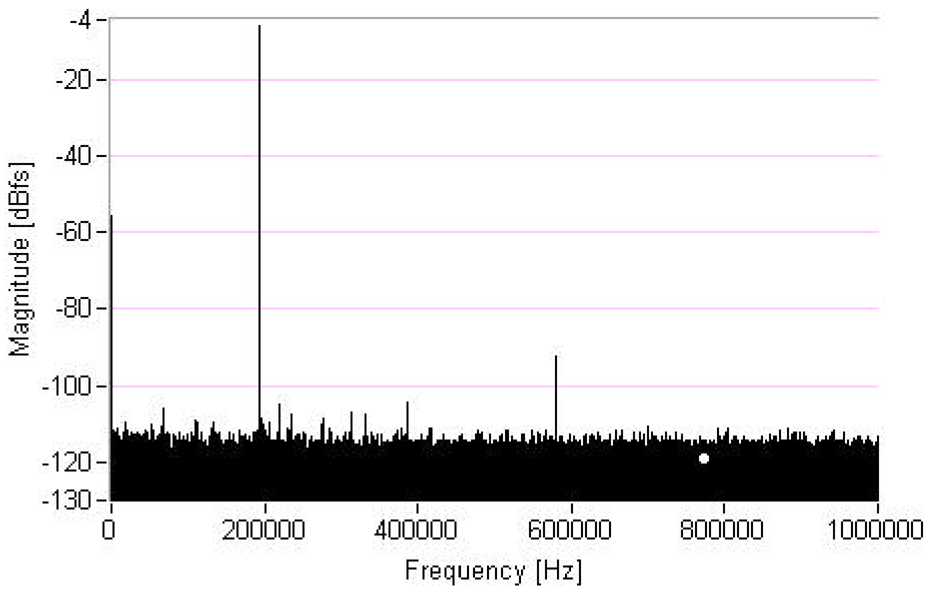

Figure 7. Spectrum of sine wave signal (+/- 1 $V_{pk,}$ 193.5 kHz) – measured with band pass filter; sampled by E1430A (input range +/- 1V_{pk}, DC,131072 samples, effective sample rate 2.5 MSa/s; antialias filter on)

ACKNOWLEDGMENT
The project has been supported by the Grant Agency of the Czech Republic (grant No. 102/99/0775). A part of the application software was written by Ing. Tomas Jakl.

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