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

DSP APPLICATION TO THE PORTABLE VIBRATION EXCITER

***W. Barwicz* [1]*, P. Panas* [1] *and A. Podgórski* [2]**
[1] Svantek Ltd., 01-410 Warsaw, Poland
Institute of Radioelectronics, Faculty of Electronics and Information Technology
[2] Warsaw University of Technology, 00-665 Warsaw, Poland

Abstract: In the paper a new portable battery operated exciter dedicated for the calibration of the mechanical vibration sensors (transducers) is presented. This instrument is based on the Motorola's digital signal processor DSP 56167 [1] which is quite new approach to the construction of such instrument. The DSP with the reference sensor [2] used as an information source about the generated vibration signals constitutes the measurement system. This system is used for the generation of the reference mechanical vibrations. The digital approach to the calibration ensures the new level of the performances. Programmability of the generated vibration amplitude, frequency accuracy and the level of total harmonic distortions (THD) overcomes all other designs available on the market.
Keywords: DSP, vibration exciter, calibration of vibration sensors

1 INTRODUCTION

The parameters of the existing analogue portable vibration exciters (calibrators) [3], [4] are not satisfactory. The maximum load for the classic analogue handheld exciters is not so high and can not be changed in the wide range. The frequency accuracy of the generated sinusoidal signal is also not good enough. Finally, these units can not be programmed in order to generate the different signals in amplitude. The frequency inaccuracy results in additional velocity and displacement errors. This is the reason for the investigations with the application of the digital technology [5], namely digital signal processor (DSP), for the improvement of these parameters. The introduction of the DSP to the mechanical construction of the exciter enables one to generate the vibration signal with the very good compensation of the harmonic components. The usage of the DSP ensures the compact, flexible construction which is not possible to obtain on the analogue way. In the exciter taken under consideration there exists the non-linear mechanical system which parameters are unknown and highly dependent from the environmental conditions. The main source of the undetermined transfer function are the vibration sensors with the different masses and the base the instrument is placed on (the stable table, hand etc.). The aim of the DSP is to find out the transfer function of the mechanical system in the current conditions and the syntheses of the sinusoidal vibration signal. The DSP has to realise the negative feedback circuit in which the amplitude of the generated vibrations is stabilised with the high precision and the harmonic components of the signal are negligible thanks to the compensation procedure. The implemented algorithm has to be adapted to the changing external situation.

2 BLOCK DIAGRAMME OF THE DEVELOPPED ALGORITHM

The block diagram of the developed algorithm for the stabilisation and the compensation of the harmonic components of the generated signal in the vibration exciter is presented in Fig. 1. The digital processor introduced in the construction of the vibration exciter has to:

- generate the signal stimulating the mechanical system;
- analyse the spectrum of the signal coming from the reference transducer;
- stabilise the amplitude of the mechanical vibrations on the required level;
- search the compensation signal for the harmonic components.

The tasks which DSP has to fulfil are shortly presented in the following parts of the paper.

3 THE TASKS OF THE DIGITAL SIGNAL PROCESSOR

3.1 The generation of the signal exciting the mechanical system

The system of the signal generation works in the real time. The parameters which are necessary for the signal generation are taken from the searching module and from the stabilisation module. These parameters are as follows: the amplitudes of the harmonic components and their phases related to the base harmonic component. On the base of these data the DSP calculates and syntheses the components of the final output exciting vibration signal.

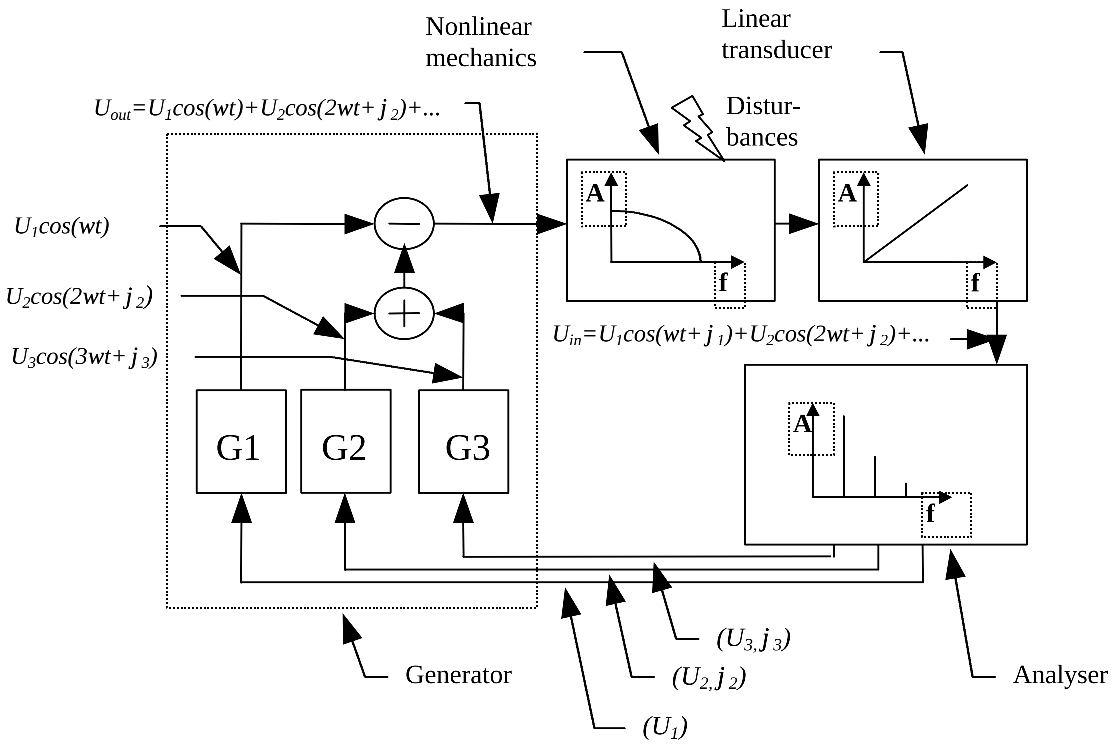

Figure 1. The block diagram of the algorithm for the stabilisation and the compensation of the harmonic components of the generated signal in the proposed realisation of vibration exciter.

3.2 The stabilisation of the mechanical system vibration on a required level

The aim of the vibration exciter is the generation of the highly stable vibration signal with the amplitude defined by the standards. In the feedback circuit the measurement of the generated signal is performed and the comparison with the reference level defined in the programme is done. Too high amplitude of the generated signal forces the decrease of this parameter in the DSP programme and too small - the increase. The stabilisation of the amplitude is performed on-line with the high precision. The information about the amplitude of the vibration signal are taken from the module of the spectrum analysis.

3.3 The measurement of the coefficient of the mechanical system attenuation

The mechanical system of the exciter is described by the certain resonance characteristic (the different frequencies are attenuated differently). For the practical reasons the resonance frequency of the mechanic part of the instrument is closed to the working frequency of the instrument. Such solution ensures the small attenuation of the required frequency and the big attenuation for the harmonic components far from the resonance frequency. The additional feature of such solution is its power saving very important in the portable instrument (in the resonance the amount of the energy required for the vibration signal with the desired amplitude is relatively low). The measurement of the coefficient of the harmonic frequency attenuation is important. This parameter is used by the module which searches the compensation signal for the exact determination of the parasitic harmonic amplitudes to be compensated.

3.4 The spectrum analysis of the signal from the reference sensor

Non-linearity of the mechanical system causes the appearance of the harmonic components in the spectrum [6] of the vibration signal. The spectrum of the feedback signal from the reference transducer built-in in the exemplary analogue calibrator and the spectrum from the standard transducer mounted on the exciter are presented in Fig. 2a and Fig. 2b – respectively. The observed value of the THD coefficient for the transducer mounted on the exciter is usually on the level 2÷3 % (cf. Fig. 2b).

a) **b)**

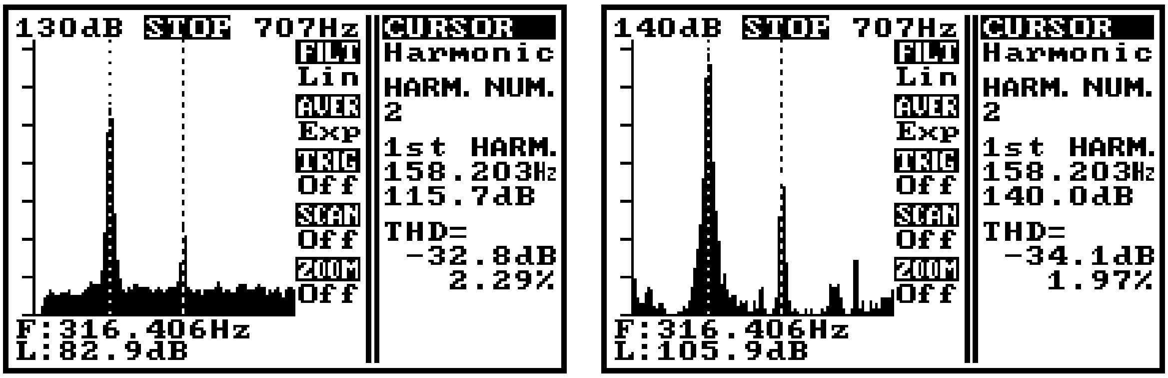

Figure 2. The spectrum of the feedback signal from the reference transducer built-in in the exemplary analogue calibrator (a) and the spectrum from the standard transducer mounted on the exciter (b).

The module of the spectral analysis built-in the exciter searches the harmonic components, determines their amplitude and the phase related to the main harmonic. These data are transferred to the module which searches the compensation signal.

3.5 The searching of the compensation signal

In the real systems the excitation of the non-linear mechanical system with the sinusoidal signal leads to the complex vibration signal which is composed by the multiple frequencies components. In order to excite the sinusoidal vibration in the non-linear mechanical instrument the generated signal must be complex. In the practice such signal can be built from the few sinusoidal signals with the frequencies equal to the main harmonic component and its multiplies. The knowledge of the phases and the amplitudes of the components is also very important. The harmonic components should be generated with the opposite phase and the amplitudes proportional to those obtained from the mechanical system. This module on the base of the data obtained from the spectrum analysis and the previous state of the system calculates the parameters and applies them to the module which generates the output signal.

4 RESULTS

The results obtained after the implementation of the stabilisation and compensation algorithm in the DSP introduced in the analogue vibration exciter are shown in Fig. 3.

a) **b)**

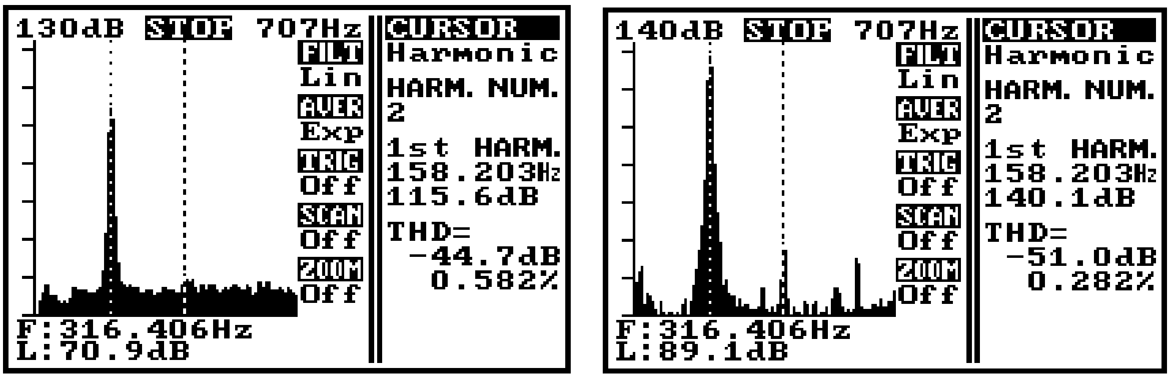

Figure 3. The spectrum of the feedback signal from the reference transducer built-in in the exemplary analogue calibrator (a) and the spectrum from the standard transducer mounted on the exciter (b) after compensation algorithm implementation in the DSP.

In the spectrum of the signal from the reference transducer the second harmonic component is on the level of the internal noise (cf. Fig. 3a). The spectrum from the standard transducer is free from this noise (cf. Fig.3b). The different values on both figures comes from the different reactions of these two transducers on the same signal. The reference transducer returns the value of the voltage corresponding to the given amplitude of the vibration, while the standard transducer returns the value of the electrical charge proportional to this signal. The time required for the digital compensation of the harmonic components is usually equal to 15÷20 s. The observed value of the THD coefficient for the calibrated sensor is on the level of 0.2÷0.3 % and is not bigger than 0.5 %.

The full description of the performed investigations and obtained results are presented in [7]. The data specification of the vibration exciter, which model is now under tests going before the introduction the unit on the market, with the comparison to the classic analogue instruments manufactured by world well-known producers (RION [8], PCB PIEZOTRONICS [9] and BRUEL & KJAER [10]) is presented in the Table 1.

Table 1. The data specification of the different vibration calibrators.

Producer	RION	PCB PIEZOTRONICS	BRUEL & KJAER	SVANTEK
Model	VE-10	394C06	4294	SV10A
Frequency	159.2 Hz ±1% (-10°C ÷ +55°C)	159.2 Hz (±1%)	159.2 Hz	159.15 Hz ±0.01 Hz
Acceleration	10 ms^{-2} (RMS) ±3% (10°C ÷ 40°C) ±5% (-10°C ÷ 55°C)	1.00 g (RMS) (9.81 ms^{-2})	10 ms^{-2} (RMS) ±3%	Programmable; for up to 120 grams: 10 ms^{-2} (RMS) 10 ms^{-2} (PEAK) 1.00 g (RMS) 1.00 g (PEAK) for up to 220 grams: 1 ms^{-2} (RMS) 1 ms^{-2} (PEAK) 0.10 g (RMS) 0.10 g (PEAK) (accuracy ±1.5%)
Velocity	10 mm/s (RMS) ±4% (10°C ÷ 40°C) ±6% (-10°C ÷ 55°C)	0.39 in/s (RMS) (9.81 mm/s)	10 mm/s (RMS) ±4%	Programmable; for up to 120 grams: 10 mm/s (RMS), etc for up to 220 grams: 1 mm/s (RMS), etc. (accuracy ±1.5%)
Displacement	10 μm (RMS) ±5% (10°C ÷ 40°C) ±7% (-10°C ÷ 55°C)	0.39 mil (RMS) (9.81μm)	10 μm (RMS) ±5%	Programmable; for up to 120 grams: 10 μm (RMS), etc for up to 220 grams: 1 μm (RMS), etc. (accuracy ±1.5%)
Maximum Load	70 grams	210 grams	70 grams	120 grams 220 grams
Transverse Amplitude	<5% of main axis amplitude	<3% of main axis amplitude	<5% of main axis amplitude	<7% of main axis amplitude
Total Harm. Distortion	<3% (20 g ÷ 60 g) <5% (10 g ÷ 70 g)	<2% (0 g ÷ 100 g) <3% (100 g÷200 g)	<3% (20 g ÷ 60 g) <5% (10 g ÷ 70 g)	<0.5%
Temperature range	-10°C ÷ +55°C	-10°C ÷ +55°C	10°C ÷ +55°C ±3% -10°C ÷ +55°C ±5%	-10°C to +55°C
Power Supply	IEC 6LR61 9V battery	4 ”AA” alkaline	6LF22 9V alkaline	2 “AA” NiMH recharg. battery
Dimensions	51 mm (diameter) x 134 mm	56 mm (diameter) x 200 mm	52 mm (diameter) x 150 mm	64 x 64 x 130 mm
Weight	600 g with battery	900 g	500 g with battery	600 g with battery
Mounting thread		10-32 UNF	10-32 UNF	10-32 UNF

5 CONCLUSIONS

The application of the DSP to the mechanical system of the vibration exciter seems to be successful. It ensures the miniaturisation and the energy saving so important for the portable instruments. The construction is flexible and enables one to work in many modes. The number of external elements of adjustment is minimised. The good reference sensor ensures very good accuracy of the measurements. The system can adapt itself to the new external working conditions. The instrument is nearly independent from the strain ageing of the elements and can be easily recalibrated in the “digital” way. The presented vibration exciter can work with the wide range of the masses of the calibrated vibration sensors in the comparison to the analogue solution. It has the best relation between the mass of the calibrated transducer to its own mass. The THD coefficient is significantly lower in relation to the analogue instruments. The frequency accuracy is extremely good in comparison to the other market existing exciters. This accuracy ensures that the error in the case of the calibration of the velocity and displacement transducers rests on the same level as for the acceleration sensors.

REFERENCES

[1] DSP 56167 Product Information and Manual; Motorola.
[2] Wilcoxon, Research Industrial Vibration Sensors, Product Catalogue.
[3] PCB PIEZOTRONICS, Calibration Equipment, Product Catalogue, 1995.
[4] M. Serridge, T. O. Licht, Piezoelectric Accelerometers and Vibration Preamplifiers, Theory and Application Handbook, Bruel & Kjaer Rev. Nov. 1987.
[5] A.V. Oppenheim, R. Schafer, Digital Signal Processing, Prentice-Hall, Englewood Cliffs, NJ, 1975.
[6] E.Oran Bringham, The Fast Fourier Transform and its Applications, Prentice-Hall, En. Cliffs 1988.
[7] P. Panas, Digital Handheld Calibration Exciter Supported by DSP56167, Master Thesis, WTU, Faculty of Electronics and Information Technology, Warsaw, 1999.
[8] RION VE-10 Specifications: http://www.hutch.com.au/~acoustic/ve10_specs.html.
[9] PCB PIEZOTRONICS: Vibration Calibrators: http://www.pcb.com.products/calibration/cal394c06.html.
[10] BRUEL & KJAER Vibration Transducer Calibration Equipment: http://www.bk.dk/5000/5252.html.

AUTHORS: Assist. Prof. Ph.D. Andrzej PODGÓRSKI, Institute of Radioelectronics, Faculty of Electronics and Information Technology, Warsaw University of Technology, 00-665 Warsaw, ul. Nowowiejska 15/19, Poland, Phone Int. +48 22 660 54 53, Fax Int. +48 22 825 52 48,
E-mail: a.podgorski@ire.pw.edu.pl
M.Sc. Wies³aw BARWICZ and M.Sc. Piotr PANAS Svantek Ltd, 01-410 Warsaw, ul. ks. Jana Sitnika 1 m. 68, Poland, Phone/Fax Int. +48 22 828 80 39
E-mail: wbarwicz@svantek.com.pl and office@svantek.com.pl