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Digital Stochastic Measurement and Industry 4.0

Platon Sovilj[1], Dragan Pejić[1], Marjan Urekar[1], Sanja Mandić[1],

[1] *University of Novi Sad, Faculty of Technical Sciences, Serbia, platon@uns.ac.rs, pejicdra@uns.ac.rs, urekarm@uns.ac.rs, sanja.mandic@uns.ac.rs*

***Abstract* – Digital stochastic measurement methods were developed in the past, with the focus onto "measurement over interval" strategy and use of stochastic dither signals. These methods obtained the increase of effective precision from low-precission A/D converters. Combination of simple analog hardware and state-of-art digital modules makes these methods suitable in many applications.Development of 4th industrial revolution (often named as Industry 4.0 concept) is extensivelly based on communication technologies advancement. This advancement enhanced microprocessor and integrated circuits based technology capabilities. The concept of digital stochastic measurement has many advantages which can be applied in Industry 4.0 concept.**

I. INTRODUCTION

Stochastic digital measurement approach is the name for a special approach of signal measurement which, with the use of an A/D converter and the addition of a stochastic dither, has as its main feature measurement over an interval, in contrast to classic digital measurement which is based on point measurement. The stochastic digital measurement approach proves to be suitable not only for measuring time-invariant and simple-periodic signals, but also for measuring harmonics of a stationary signal, with controlled noise suppression.

Development of 4th industrial revolution (often named as Industry 4.0 concept) is extensivelly based on new communication technologies development. This development further extended microprocessor and integrated circuits based technology capabilities. The concept of digital stochastic measurement has many characteristics which can be used for challenges noticed in Industry 4.0 concept.

II. FUNDAMENTALS OF DIGITAL STOCHASTIC MEASUREMENT

In [1] high-precision stochastic Watt-hour meter is proposed. It was based on a stochastic measurement method, containing circuits for analog addition, stochastic dither signal added to the iinputs, analog comparators, analog level limitters and logical multiplzing circuits. Accuracy limit of this high-precision stochastic Watt-hour meter is considered. The device main hardware elements are presented at Figure 1.

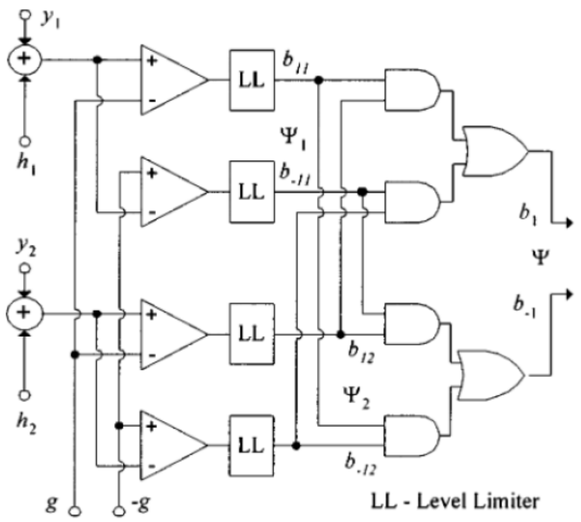

Fig. 1[1]. Main hardware elements of the high-precision stochastic Watt-hour meter. It contains circuits for analog addition, stochastic dither signal added to the iinputs, analog comparators, analog level limitters and logical multiplying circuits

In [2] further generalization of low-frequency true RMS instrument based on stochastic measurement approach is considered. It was based on an improved stochastic measurement method, containing also circuits for analog addition, stochastic dither signal added to the iinputs, but analog comparators, analog level limitters and logical multiplying circuits are replaced with 6-bit A/D converter and FPGA structure (Figure 2).

Microcontroller is getting outputs from FPGA structure and, after basic processing, forward them to the computer by serial communication channel. Prototype instrument and FPGA based core block diagram are presented at

Figure 3. FPGA structure is consisted of A/D driver, LFSR register, synchro element, counter, appropriate memory and implementation of multipliers and accumulators, digital multiplexers and UART communication module.

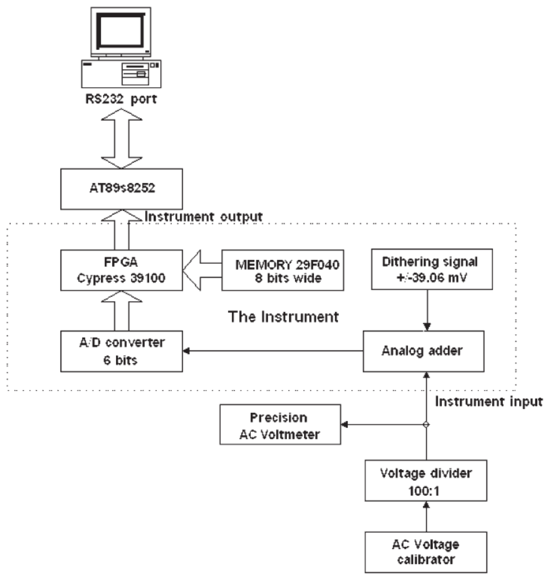

Fig. 2[2]. Further generalization of low-frequency true RMS instrument based on stochastic measurement approach: instrumentation block diagram.

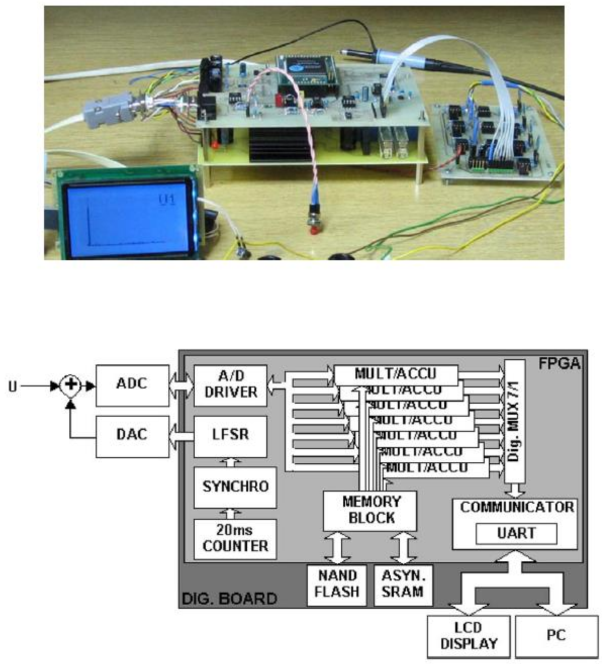

Fig. 3[2]. Further generalization of low-frequency true RMS instrument based on stochastic measurement approach: prototype instrument and FPGA based core block diagram.

III. DEVELOPMENT OF DIGITAL STOCHASTIC INSTRUMENTATION AND INDUSTRY 4.0

A stochastic instrument is proposed in [3] for stochastic measurement of harmonics at low signal-to-noise ratio (Figure 4). Relative standard uncertainty for both Gaussian and uniform noise is simulated and averaged (Figure 5) indicating the further direction of stochastic instrumentation development.

Fig. 4[3]. A stochastic instrument proposed in [3] for stochastic measurement of harmonics at low signal-to-noise ratio.

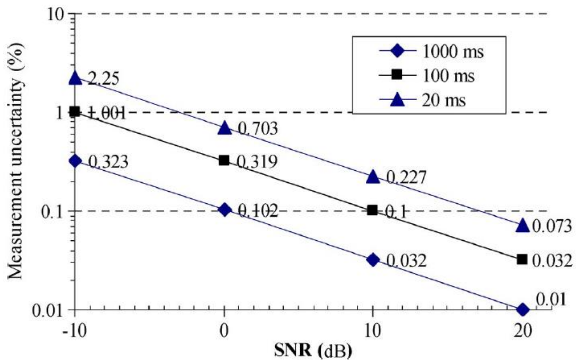

Fig. 5[3]. Relative standard uncertainty for both Gaussian and uniform noise (simulation average) of a stochastic instrument proposed in [3] for stochastic measurement of harmonics at low signal-to-noise ratio.

The research described in [4] evaluated one implementation of digital stochastic measurement of non-stationary signal (Figure 6). The simulations and experiments showed well agreement with the developed formula for measurement uncertainty limit.

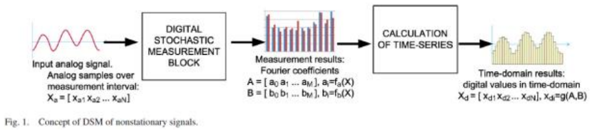

Fig. 6[4]. Digital stochastic measurement of a non-stationary signal with an example of EEG signal measurement: instrumentation block diagram.

The research described in [5] evaluated a design of low power stochastic sensor in IoT, IIoT and Industry 4.0 environments. The sensor model (Figure 7) is consisted of transducing element, digital stochastic measurement module and IioT module.

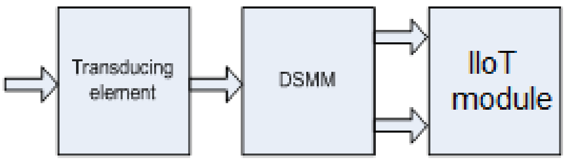

Fig. 7[5]. Model of a single stochastic sensor with IIoT module for industrial applications (SSUIA).

IV. CONCLUSION

Stochastic digital measurement strategy is the name for a special set of methods of signal measurement which, with the application of an A/D converter and the addition of a stochastic dither signal, has as its key characteristics measurement over an interval, which is opposite to typical digital measurement which is based on measurement in a point. The stochastic digital measurement strategy appears to be usefull not only for measuring time-invariant and simple-periodic signals, but also for measuring harmonics of a stationary signal, with determined noise suppression.

Development of 4th industrial revolution (often named as Industry 4.0 revolution) is mainly based on new communication technologies development. This development further extended microprocessor and integrated circuits based technology characteristics. The strategy of digital stochastic measurement has many usefull properties which can be applied for solving problems present in Industry 4.0 concept.

REFERENCES

[1]D. Pejic, V. Vujicic, “Accuracy limit of high-precision stochastic Watt-hour meter,” IEEE Trans. Instrum. Meas., vol. 49, pp. 617-620, June 2000.

[2]V. Pjevalica and V. Vujičić, “Further generalization of low-frequency true RMS instrument,” in Proc. Instrumentation and Measurement Technology Conference IMTC 2005, pp. . May 2005.

[3]B. Santrač, M. A. Sokola, Z. Mitrović, Ivan Župunski and V. Vujičić, “A Novel Method for Stochastic Measurement of Harmonics at Low Signal-to-Noise Ratio”, IEEE Trans. Instrum. Meas., vol. 58, pp. 3434-3441, Oct. 2009.

[4]P. Sovilj, S. Milovancev, and V. Vujicic, “Digital stochastic measurement of a nonstationary signal with an example of EEG signal measurement,” IEEE Trans. Instrum. Meas., vol. 60, no. 9, pp. 3230–3232, Sep. 2010.

[5]Marjan Urekar, Platon Sovilj, Ivan Gutai, Dragan Pejic, Bojan Vujicic, Djordje Novakovic, “Low Power Stochastic Sensor in IoT, IIoT and Industry 4.0 Environments”, 24th IMEKO TC4 International Symposium, 22nd International Workshop on ADC and DAC Modelling and Testing, IMEKO TC-4 2020, Palermo, Italy, September 14-16, 2020.