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MODELLING AND SIMULATION OF MEASURING SYSTEMS USING THE SIMULINK SPECIALISED TOOLBOX

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Abstract: The paper shows the contents, application and way of using the specialised Toolbox for the SIMULINK language, which is designed for modelling and simulating measuring systems. This toolbox contains 22 models of measuring system elements and the block descriptions are accessible in Polish and English.
Keywords: measuring systems, SIMULINK

1 INTRODUCTION

The problems of modelling and investigation of simulating measuring devices are present in metrology since app. 30 years. In the Metrology Department of the Academy of Mining and Metallurgy the first computerised simulating studies of A/D converters were carried out in 1973. Applied were the structural method of mathematical modelling and the simulating language GODYS, designed for simulation of continuous dynamic systems [1,2]. Aim of the modelling and simulating studies was from the beginning the analysis of meteorological properties, especially of dynamic characteristics, of measuring devices, and measuring channels [3,4]. In the seventies and eighties new A/C transducers, new sensors, and in effect, computerised measuring systems were originated. The development of information technology meant faster computers with a larger capacity, and new programming languages, including simulating languages, which in effect increase the scope of simulating studies. This means also widening the range of simulating studies, particularly on computer aided design of measuring channels and systems.

Design problems raised in metrology the question of selecting proper quality criteria (combined errors) of measuring systems. Various forms of quality criteria were devised and investigated, dividing them principally according to the aims of the system [5,6]. Some criteria were suggested e.g. for the identification of measuring systems, and other ones for diagnostic or information systems [7,8,9]. Computerised design forced at the same time an ever better (deeper) modelling of system elements, modelling of a wide groups of devices, and in effect the creation of libraries of most frequently used models for measuring system elements.

The simulating language GODYS was constantly adapted to new computers and the increasing demands of simulating studies. Incorporating the possibility to simulate discrete systems, then the internal parametrical optimisation packet, and finally the possibility to construct and use subroutines and libraries of subroutines expanded the language. It was thus possible to create libraries of measuring system element models. The first library of the GODYS PC language contained 29 models of measuring system elements, including models of sensors for non-electric quantities, various types of A/D converters, and supporting systems like e.g. separators or multiplexers [10]. Scientific research and student teaching enabled continuous widening of the library, especially by models of specific devices used in measuring systems [11]. Since its beginning, the library was aimed at analog and analog-digital elements, leaving out models of the digital group, such as interfaces or microprocessors.

2 THE TOOLBOX OF SIMULINK „MEASURIG SYSTEMS”

Among the new tools for simulation of technological devices a particular place is held by MATLAB&SIMULINK [12], principally due to its wide scope of mathematical modelling and the comfortable graphic interface. The first versions of SIMULINK had no specialised standard blocks for analysing and designing measuring systems. That led to the idea to move into it several standard operations and the library of GODYS-PC in the shape of m-files [13]. In this way the first version of the metrologically specialised toolbox for SIMULINK was generated. The toolbox „Measuring Systems” , developed for the new version of SIMULINK, contains 22 models (blocks) of measuring system elements:

1. four force sensors (model in the form of static and dynamic characteristics)
2. tensometric sensors in bridge form
3. four temperature sensors (model in the form of static and dynamic characteristics)
4. resistive temperature sensor (definition model)
5. rate generator (model in the form of static and dynamic characteristics)
6. Wheatstone bridge
7. transformer separator 1 (circuit model)
8. transformer separator 2 (transmittance model)
9. transformer separator 3 (low-pass filter model)
10. A/D converter – ideal model
11. A/D converter – with pulse-time conversion
12. A/D converter – with weight compensation
13. A/D converter – with double integration
14. A/D converter – with delta conversion
15. sample&hold system
16. voltmeter for mean value, rms value, and maximum value (ideal model)
17. active power, reactive power, and apparent power meter
18. time, frequency and phase meter
19. watt-hour meter
20. analog multiplexer (ideal model)
21. analog multiplexer (controlled potential divider model)
22. analog demultiplexer (ideal model)

Most of these models of transducers or measuring instruments only reproduce the conversion or the measuring principle (e.g. on the base of a block diagram), but also enable access to the model parameters, so that in effect one can simulate the realisation of a particular measuring instrument. The paper presents a wider description of these models. The toolbox „Measuring Systems" is being constantly expanded and the block descriptions are accessible in Polish and English.

3 DESCRIPTION OF SOME SELECTED COMPONENTS OF THE "MEASURING SYSTEMS" TOOLBOX

As examples, the following models of the measuring tools contained in the "Measuring Systems" Toolbox will be presented:

a. a model of the rate generator,
b. a model of the analogue multiplexer, and
c. a model of the ideal A/D converter.

The rate generator is used as the sensor of the rotational speed expressed in revolutions per time unit. A mathematical model of the rate generator was adopted as the characteristic conforming to the Polish standard:

$$U_{wy} = K \cdot N + K_0 \cdot N^2 + K_1 \cdot \sin(p \cdot N \cdot t) \tag{1}$$

where :
K – static characteristic coefficient
K_1 – coefficient showing the influence of pulsation
K_0 – coefficient showing the level of non-linearity related to the rate generator class K_L throug the relationship:

$$K_0 = \frac{K_L \cdot K}{N_{max} \cdot (100 - K_L)} \tag{2}$$

N - is the model input, the voltage, U_{wy} - is the output. Model parameters are: N_{max}, K_L, K and K_1. The rate generator model dialog box is presented in Fig. 1.

The analog multiplexer can be modeled as ideal or real. Both models are contained in the toolbox under consideration as separate components.

An ideal multiplexer model performs switching of N input parallel channels into one output channel with a pre-determined time interval, T_p, of one input sampling. So the model parameters are: the number of inputs, N, (maximum eight) and T_p . Sampling frequency of each of the input quantities can be defined as $f_p = 1/(T_p \cdot N)$. Likewise, an ideal demultiplexer model can be constructed.

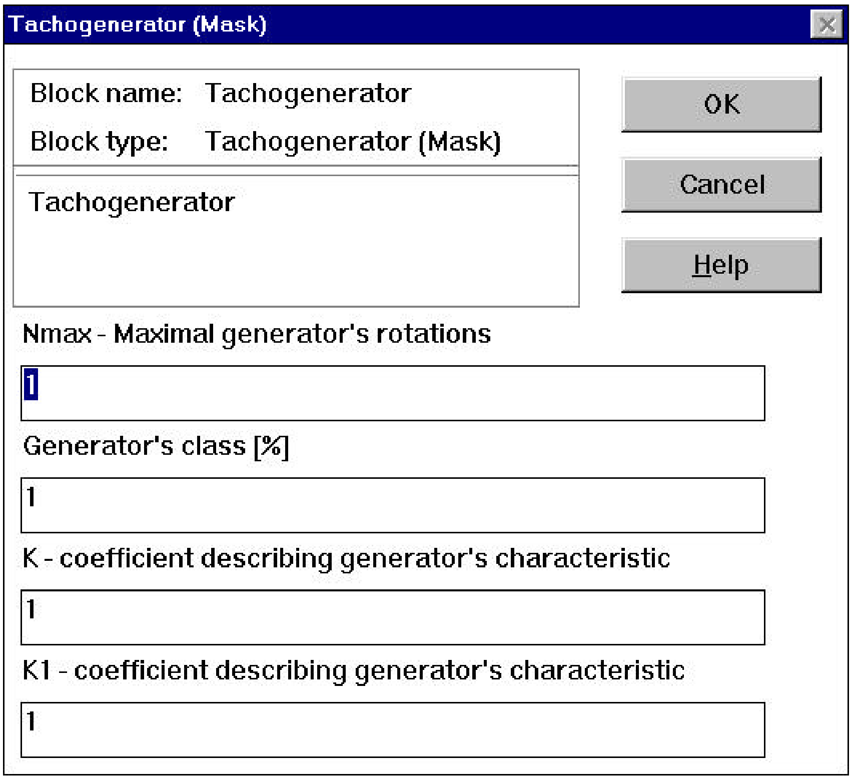

Figure 1. The rate generator model dialog box

The analog multiplexer model dialog box is presented in Fig. 2.

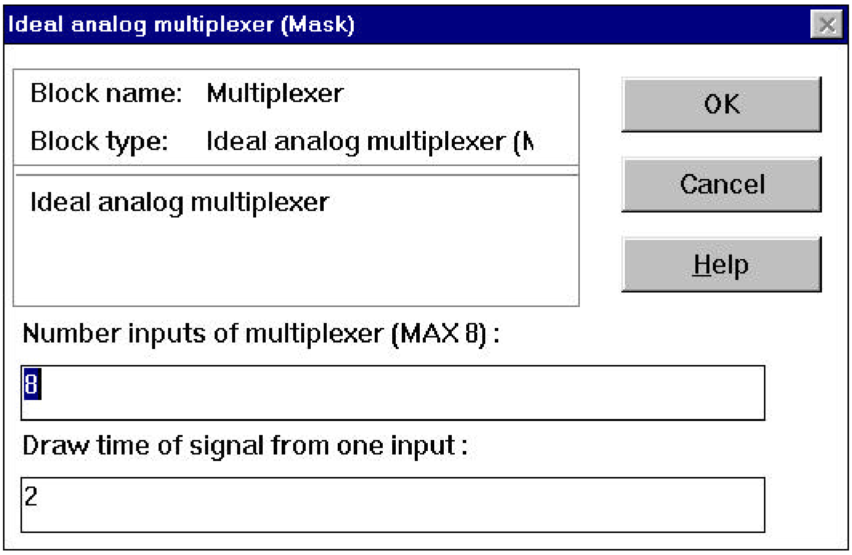

Figure 2. The analog multiplexer model dialog box

The second analog multiplexer model presents the multiplexer as a controlled voltage divider with eight inputs at maximum. The voltage divider consists of the sample&hold system (following the multiplexer) input resistance and the resistances of the keys in the individual channels, varying with the sampling frequency. The model parameters are: the number N of the multiplexer inputs (in both models the switching order from 1 to N was assumed), the sampling time T_p, the resistances of the open and shorted keys (in both models it was assumed that all keys are identical) and the sample&hold system resistance. The dialog box of the analog multiplexer modeled as the voltage divider is presented in Fig. 3.

The "Measuring System" Toolbox contain a few models of A/D converters, differing both in the principle of operation and the particular realization. A model of an ideal A/D converter is a specific one in this group, as it covers an ideal, mathematical realization of the sampling and quantization operations. The coding operation was not modeled: it was assumed to be errorless. The model output is therefore in the decimal code, which can be understood as the output after the ideal D/A operation.

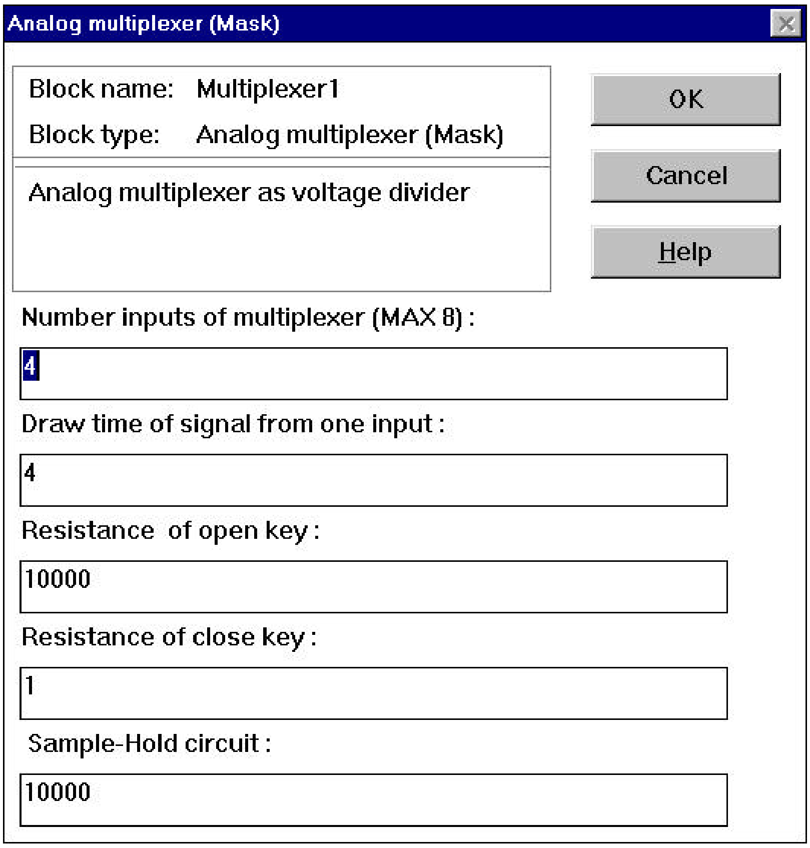

Figure 3. The dialog box of the analog multiplexer modeled as the voltage divider

The ideal model of an A/D converter is used in simulation research of measuring systems as an approximate model when the A/D converter error is negligible compared to the errors of the remaining part of the system, or as the reference model used for calculating errors of the real system models. So the model of an ideal A/D converter is a quantizator model for the input signal multiplied by the unit rectangular pulse modeling the sampling. So the parameters of the converter are: the voltage range and the bit number (these two quantities determine the magnitude of the quantum), and the sampling signal period and modulation. Moreover, an additional parameter was introduced: the converting time i.e. the ideally modeled delay in result producing. This parameter is used in approximate modeling of A/D converters; in other cases its value may be taken as zero. Likewise, through the appropriate selection of the sampling signal parameters versus the parameters of processed signals and the parameters of simulation, the operation of sampling in the ideal A/D converter model may be neglected. The model represents then only the ideal quantization operation. The ideal A/D converter dialog box is presented in Fig. 4.

In Fig. 5 a typical measuring system model constructed from the components of the "Measuring System" Toolbox is presented, where some of the above discussed elements are included. It is a four-channel model for which time courses and dynamic errors of the measuring quantities were to be determined. The models of forcing quantities for the system were the sums of the constant and sinusoidal variables.

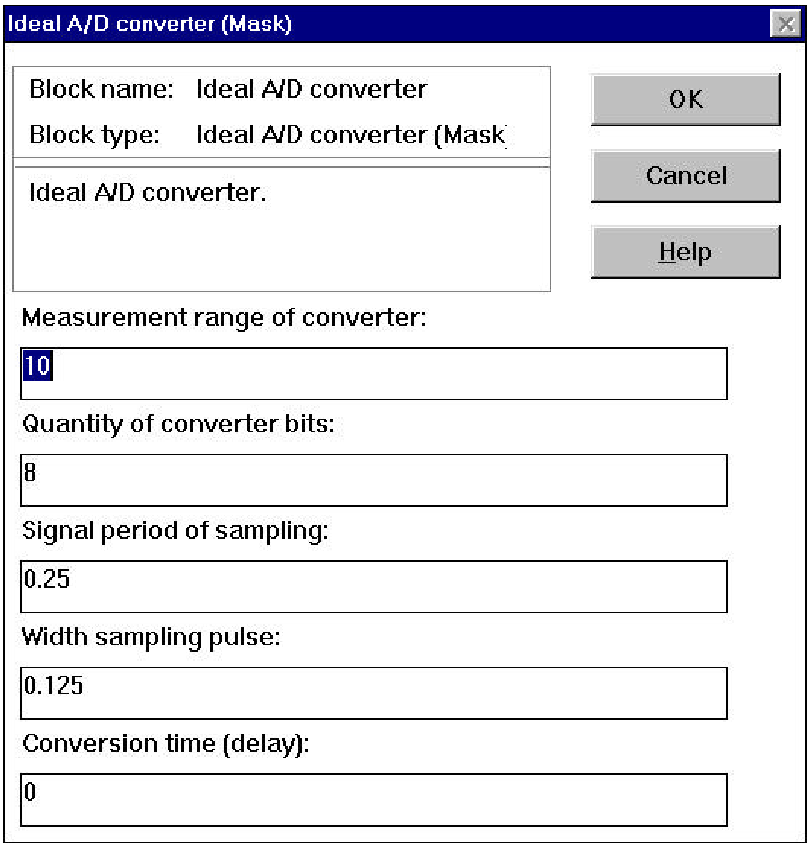

Figure 4. The ideal A/D converter dialog box

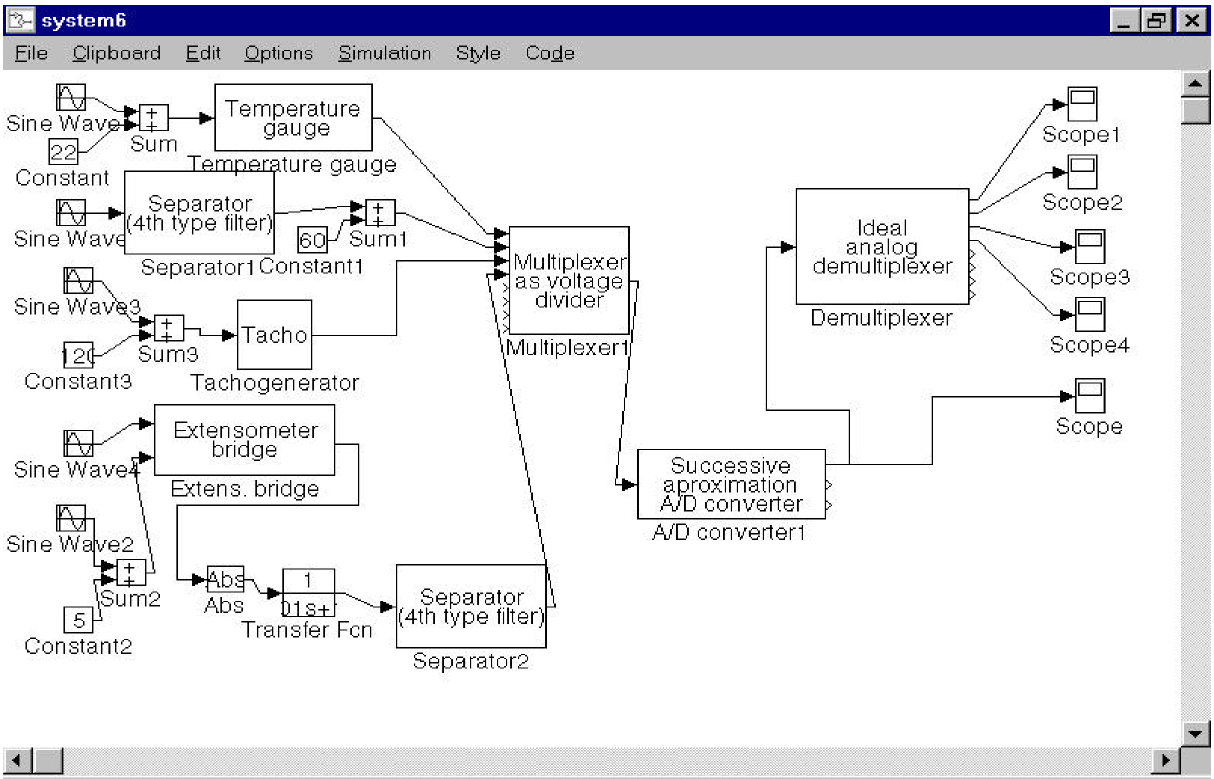

Figure 5. A typical measuring system model

3 CONCLUSIONS

The contents and applications of the "Measuring System" Toolbox, newly developed for the user of SIMULINK is presented in the paper. This toolbox was developed in the course of the author's many-year experience in the field of the measuring system modeling and simulation research. The conclusions drawn from its up-today use confirm its full applicability both to scientific research and to the didactics of metrology. Thanks to the didactics, it is still corrected and completed. The possibilities of MATLAB, SIMULINK and other SIMULINK toolboxes, still extending, now completed with the "Measuring System" Toolbox, offer the metrologist a very effective tool for measuring system modelling and simulation research.

REFERENCES

[1] M. Szyper, J. Nalepa, A. Wojtasik, Measuring System Analysis with Digital Simulation of Structural Models, Proceeding VII Congress IMEKO, London, 1976
[2] J. Gajda, M. Szyper, Modelling and Simulation of Measuring Systems; Kraków 1998, p. 411(in polish - Modelowanie i badania symulacyjne systemów pomiarowych}
[3] J. Nalepa, M. Szyper, Modelling of Measuring System by Computer Simulation, Proceedings of Conference "Simulation of Systems" ,Praque, 1983
[4] J. Nalepa, Errors of Measuring Systems and Their Evaluation by Simulation Methods, Proceedings of Conference "Simulation in Research and Development", Eger, 1984
[5] J. Nalepa, Optimization of Measuring System Parameters in GODYS-PC Simulation Language, Proceedings of Conference IMACS - European Simulation Meeting, Esztergom 1990
[6] J. Nalepa, The Quality Criteria of Measuring System and Their Evaluation by Simulation, System, Analysis, Modelling, Simulation; **8**(1991)1, p. 63-86.
[7] J. Gajda, Modelling and Optimization of Identification Process, 15-th IFIP Proceedings of Conference „System Modelling and Optimization", Zurich 1991
[8] J. Nalepa, Simulation Analysis of Diagnostic Measurement System Errors, Proceedings of Conference AMSE "Applied Modelling & Simulation" , Lviv 1993, p. 39 - 46
[9] J. Nalepa, Measuring System Design Using Computer Simulation Method, Proceedings of IMEKO TC-4 9th International Syposium on „Electrical Instruments in Industry", Glasgow 1997, p. 249-252
[10] J. Nalepa, Simulation Analysis and Design of Measurement Systems in GODYS-PC Language - Experience in Education, Proceedings of XIXth International Workshop „Advanced Simulation of Systems" ASIS 1997, Krnov 1997, p. 173-177
[11] J. Nalepa, Computer Analysis and Design in Measuring Systems Education, Proceedings of Conference KoREMA'96, Opatija, 1996
[12] MATLAB & SIMULINK for Windows - User's Guide; The MathWorks, Inc.
[13] J. Nalepa, Simulation of Measurement Systems Using SIMULINK, Proceedings of 32 Spring International Conference „Modelling and Simulation of Systems"- MOSIS'98, Sv. Hostyn 1998,vol.1 p. 155-162

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