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# THE EXAMINATION OF UNCERTAINTY DESIGNATION ALGORITHMS DEDICATED TO APPLY IN THE MEASUREMENT CHANNEL EQUIPPED WITH ADC

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**Abstract:** In this paper the idea and the selected results of numerical simulation of an uncertainty designation procedure in the measurement channel equipped with ADC is presented. The basic principles of that procedure implementation are shown in [5,6]. The assessment of correctness of the mentioned procedures is the main aim of the carried out simulations.

**Keywords:** uncertainty assessment, ADC, measurement instrument.

## 1. INTRODUCTION

The classic, commonly used instruments for the measurements and the visualisation of ship operations are realised on the basis of electromechanical meters. This state limits, to a considerable extent, the possibility of supervising and monitoring the dynamics of the controlled processes. Nowadays, the traditional analogue instruments have been mostly substituted by microprocessor measurement instruments equipped with analog-to-digital converters (ADCs).

The stand alone ADCs and ADC equipped instruments are traditionally tested as described in IEEE 1057-1994 and 1241-2000 standards [1,2,3,4]. The aim of the mentioned standards is to provide common terminology and test methods for the evaluation of ADCs and related instruments. The standards identify error sources and provide test methods to perform error measurements. They are intended to evaluate and compare the properties of the considered ADCs and instruments in the conditions that close to the laboratory conditions. Some of the mentioned standards recommendations can be used also in the instrument usage conditions.

Nevertheless, it is not possible and even not advisable to perform in the exploitational conditions the tests described in the standards. The instrument exploitational conditions can drastically differ from the laboratory ones. It is very often difficult to determine the external factors influencing the measurement process. The ship operations could be an example.

Because of the variability of the instrument usage environment, it is difficult to point out how the disturbances propagate within the instrument circuits. Finally, they affect the measurement channel characteristics changes. In such conditions another kind of test is to be considered. It would be useful to carry out the test of the instrument characteristics on-line. The main aim during the considered test should be the characteristics of channel designation and the accuracy of measurement result assessment.

Usually, in measurement operations it is important to get the measurement result with possibly high accuracy. In the ship operation practice, the assessment of accuracy of the measurement results is still omitted [7]. Such a situation is connected, among others, with difficulties to determine the measurement conditions in the ship hostile environment and quite complicate algorithms must be carried out for the result uncertainty designation since there are many factors that should be made allowances for.

Taking into account such circumstances, the appropriate measurement channel configuration and the adequate microprocessor program aided algorithms were elaborated enabling the measurement result correction as well as their uncertainty estimation and indication, for the actual instrument use conditions. The subject of the research aims at realising this idea by including the appropriate circuit configuration and program into functional tasks of the measurement instrument.

The considered procedure is performed in the following steps:

- the measurement channel auto-calibration procedure,
- designation of the actual characteristics of the measurement channel,
- correction of the measurement result and its uncertainty assessment,
- visualisation of the obtained results.

In the instrument auto-calibration phase, the input of the considered measurement channel is supplied with the signal source generating pattern, linearly rising (ramp) $u_w(t)$ voltage (Fig.1). The measurement channel consists of an analogue part (including ADC) and a digital (program) part. On the output of ADC the digital file **{Y}** is obtained, containing the elements depending on interacting factors, violating the channel characteristics and the measurement process.

In the next step, applying the linear regression method, the file **{Y}** can be used to design the elements of the **{Y'}** digital file (Fig.1) (the estimation of the **actual** characteristics of the measurement channel). The elements of the **{Y''}** file determine the digital representation of the **pattern** characteristics of the tested channel assumed by the designer of the instrument. They are calculated by a microprocessor on the basis of the course of $u_w(t)$.

The comparison of **{Y'}** and **{Y''}** files enables us to execute the measurement result correction, by removing systematical interaction effects causing the channel characteristics changes (characteristics error).

The dispersion of **{Y}** file elements in relation to **{Y''}** file elements can be used to determine the measurement result uncertainty following the rules described in [5,6,7].

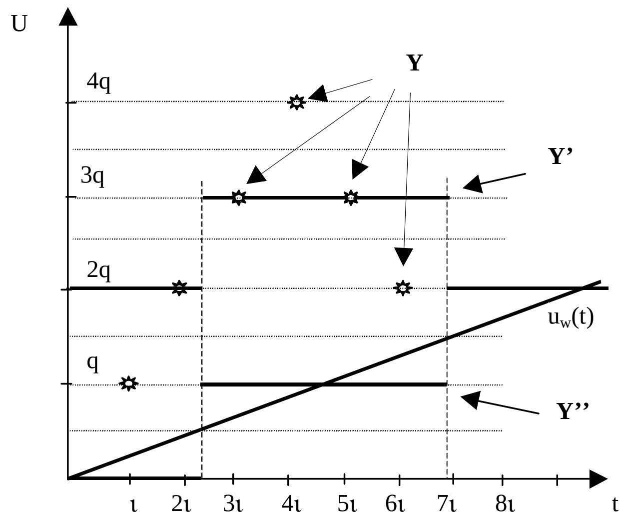


**Fig. 1. Digital representation of the input signal for the pattern and real characteristics of** the **measurement channel**

## 2. THE ALGORITHMS EXAMINATION

The examination is performed to optimise the measurement result uncertainty designation procedure. The tasks connected with the considered simulation are carried out by the integrated programming environment LabVIEW.

In the first part of the examination, during the computer simulation, the model of the whole measurement channel was applied programmatically.

The second part of the examination consists of experimental tests carried out in the real channel of a virtual instrument.

The simulations concern the above-mentioned three digital files: **{Y}**, **{Y'}** and **{Y''}**. Fig.2 shows the dependencies between the defined digital files and the procedures used to complete the set task.

In the simulation process, the measurement channel model is assumed. It is possible to apply the channel model having any desired complicity.

Similarly, the model of uncertainty designation is well-known. The input of the measurement channel is supplied with a pattern signal containing some distribution-controlled disturbances [8,9].

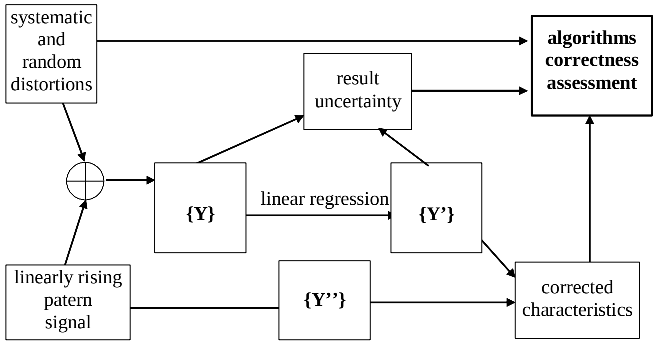


**Fig. 2. Configuration of the testing procedure**

For every discrete point, in the whole range of the channel characteristics, designated uncertainty can be compared with the uncertainty caused by input disturbance distribution.

A selected part of the simulation *Diagram* is presented in Fig.3. It contains some LabVIEW functions used to model channel properties as well as the disturbances influencing transmitted signals in the measurement channel.

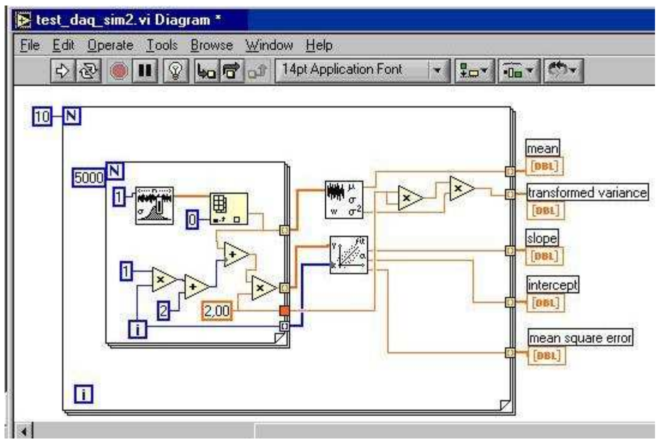


**Figure 3. The selected part of *Diagram* used in** the **simulation**

In the considered example, the characteristics of the measurement channel is described by a simple formula:

$$y = (x + 2) \cdot 2 \tag{1}$$

To each from 5000 points of the channel characteristics, the disturbance (*Gaussian white noise*) is added. The mean and variance values of an input disturbing sequence are computed. The regression function (*Linear fit*) designates the *slope* and *intercept* coefficients of the linear approximation of the input data set.

Some results of the simulations are shown in Fig.4. In this figure, for 10 exemplary results, the values of the *variance* depending on disturbance distribution and the *mean square error* of channel output elements in reference to the *best fit line* (white fields) are calculated. Almost imperceptible differences between the respective values result from the random nature of the analysed process and can confirm the assumption that applying the regression method to the *actual* characteristic of measurement channel designation is justified. The values of the *mean square error* calculated for the *best fit line* are strictly connected with the disturbance process distribution.

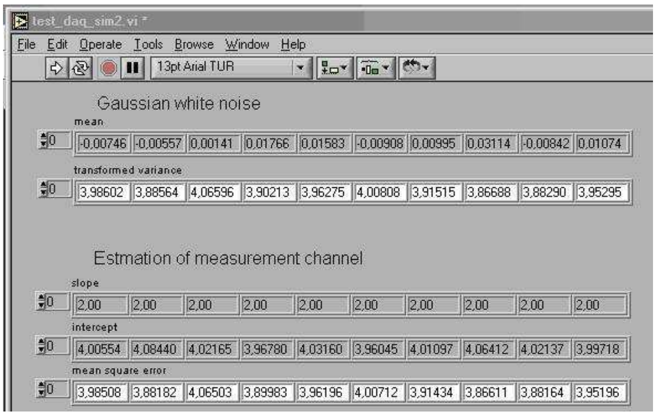


**Figure 4. A selected part of *Front panel* used in** the **simulation**

The measurement result uncertainty designation algorithms can be applied in the microprocessor measurement channel as well as in a virtual instrument, also consisting of distributed units and equipped with any kind of communication interface.

The instrument analogue channel accuracy, together with ADC properties, can be assessed using the test procedures elaborated preliminarily for examination microprocessor channel algorithms.

The voltage input of the virtual instrument has to be supplied with a suitable pattern ramp signal. The configuration of an exemplary arrangement is shown in Fig.5. The pattern source supplies the instrument input with the linearly growing voltage changing inside the input operating range. The described above digital file elements are obtained by measuring the signals, not like previously simulated in the examining program, but transmitted in the real channel. A few other procedures are common for both the presented applications.

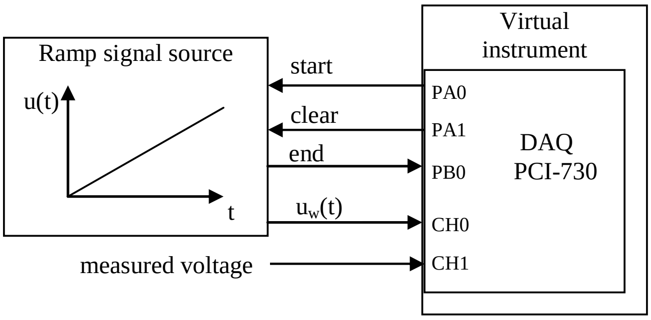


**Figure 5. The configuration of the test arrangement**

The subject of the research is the measurement channel, which consists of the *Data acquisition board* PCI-730 distributed by Eagle Technology, installed in PC and working under LabVIEW environment. The *DAQ board* is equipped with 16 analogue input channels (ADC) working with the maximal input sampling rate of 100 kS/s and also 4 analogue output channels (DAC). The resolution of the analogue inputs/outputs is equal to 14-bits. There are also present i.e. three 8-line digital I/O ports.

The *PA0* and *PA1*digital lines (Fig.5) are used for initialling the generation of the pattern ramp signal $u_w(t)$. The control signals are managed by the test program. The pattern source supplies the *CH0* input of the *DAQ board* and sends the *end* signal to the *PB0* digital line of *DAQ* after the $u_w(t)$ voltage achieves the value equal to 2,5V. The registered course of $u_w(t)$ voltage is shown in Fig.6. The pattern signal is used for designating the actual characteristics of the measurement channel.

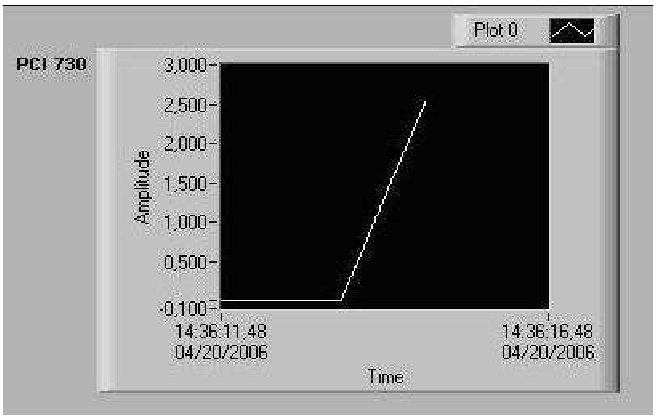


**Figure 6. The course of a pattern ramp signal**

The experimental test program is arranged with the use of LabVIEW two-frame *Sequence* structure.

During *Sequence0* of the test program (Fig.7), the channel actual characteristics for the measured data set is estimated with the regression method (*Best linear fit*). The *mean square error* (*mse*) is calculated on the basis of the measured data set and the channel actual characteristics expressed by its estimating line coefficients.

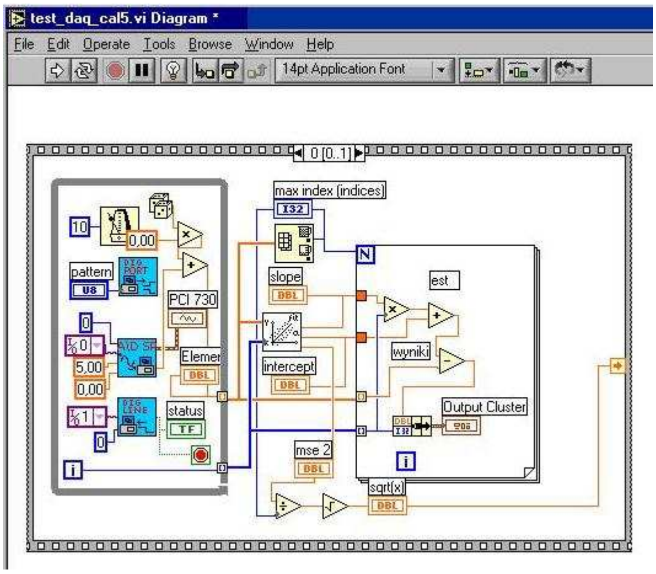


**Figure 7. The *Diagram* of** the **measurement channel characteristics designation (*Sequence0*)**

The characteristics of the measurement channel is described by the formula, also simple as in the previous simulation:

$$y=x \tag{2}$$

The test program (Fig.7) is prepared also to simulate the disturbing signals with the desired distribution (currently: uniform distribution).

During *Sequence1* of the test program (Fig.8), the measurement of input voltage in channel 1 (*CH1* analogue input – Fig.5) is carried out as well as the visualisation of the measurement results and their uncertainty (Fig.9).

In the presented conditions, the virtual voltmeter input was supplied with the measured voltage equal to 2,000(two)V. The *coverage factor* for the expanded uncertainty calculation was equal to 2 [8].

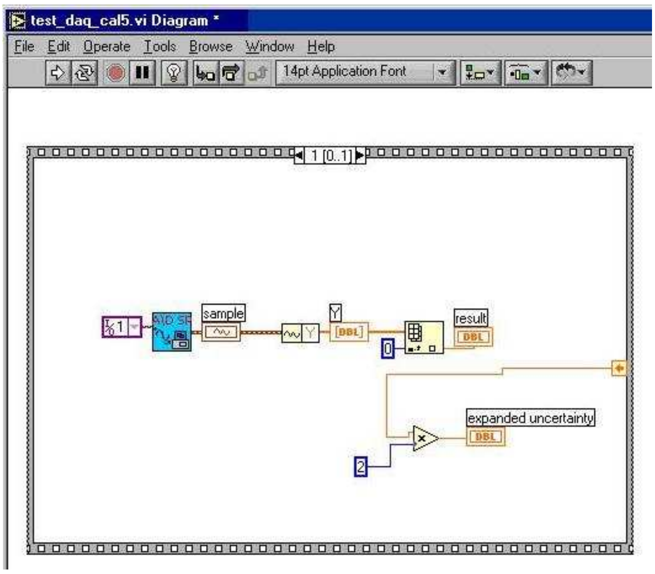


**Figure 8. The *Diagram* of** the **input voltage measurement and** the **obtained result uncertainty visualisation (*Sequence1*)**

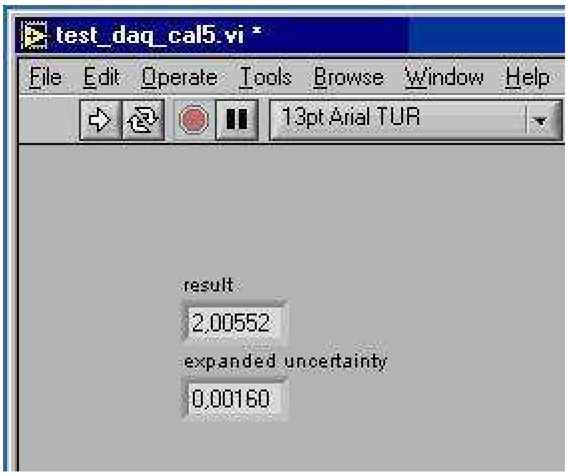


**Figure 9. The exemplary measurement result and their expanded uncertainty visualisation**

To carry out the presented examination procedures possibly clearly, some of its parts were omitted, e.g. the procedures connected with the measurement result final correction.

The examination of uncertainty designation algorithms was carried out in the measurement channel of a virtual voltmeter supported by the DAQ board. The preliminary results achieved in the experiment realistic conditions justify further investigations.

## 3. CONCLUSIONS

Under the ship operations, the measurement result uncertainty is still difficult to determine, especially in indefinable ambience conditions.

The presented investigations aim to check and optimise the algorithms of uncertainty designation applied in the program of the ADC aided measurement instrument. Those algorithms are intended to apply, first of all, in the microprocessor measurement channel. Finally, the elaborated LabVIEW application can be used for on-line accuracy estimation in the equipped with DAQ measurement channel of virtual instrumentation.

Besides the numerical simulations, the experimental tests of real measurement channel of virtual instrument were carried out.

In the paper the achieved simulation preliminary results are presented and discussed.

## REFERENCES


[1] IEEE 1057-1994, "Standard for Digitizing Waveform Recorders" , 1994.

[2] IEEE Std 1241-2000, "IEEE Standard for Terminology and Test Methods for Analog-to-Digital Converters", IEEE, NY, 2001.

[3] Arpaia P., Schumny H, "International standardization of ADC-base measuring systems – state of art", Computer Standards & Interfaces 19, Elsevier, 1998.

[4] Cruz Serra A., Alegria F., Martins M., Fonseca da Silva M., "Analog-to-digital converter testing – new proposals", Computer Standards & Interfaces 26, Elsevier, pp. 3-13, 2003.

[5] Masnicki R, Mindykowski J., "An uncertainty as a component of the measurement result of the microprocessor instruments", *IMEKO Proceedings*, Athens, Greece, vol.2, pp. 644-649, 2004.

[6] Masnicki R., "The Adaptational Procedures Applied in Microprocessor Measurement Channel", *IMEKO Proceedings*, Jurata, Poland, vol.1, pp.114-117, 2005.

[7] Masnicki R., Mindykowski J., "Measurement Accuracy Assessment in Ship Applied Instrumentation" ", *IMEKO Proceedings*, Jurata, Poland, vol.1, pp. 87-90, 2005.

[8] "Expression of the Uncertainty of Measurement in Calibration", *Publication EA-4/02*, 1999.

[9] "Guide to the Expression of Uncertainty in Measurement", *ISO*, 1995.