Modeling of data acquisition systems using the queueing theory

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**Abstract**. This paper describes the features of a data acquisition system modeling based on queueing theory method. The main elements of the studied data acquisition system structure are sample hold amplifiers and dual-slope analog digital converters. A converting time of these alarms in analog digital converters depends on signal levels and is described by an exponential distribution. In this case we present the data acquisition system as the Markov model of the multichannel queueing system with a limited queue.

**Keywords:** Data acquisition system; Queueing theory; Markov model; Analogue digital converter

1. Introduction

The continually growing flow of information provided by systems that are used to control technological processes, monitor environmental conditions, test industrial facilities and support scientific research presents increasing challenges in terms of equipment and maintenance costs, as well as timing of information delivery [1,2].

 Data acquisition systems (DAS), comprising a set of hardware for sampling, conversion, storage and primary processing of input analogue signals received from sensors installed, for example, at industrial facilities, offer an approach towards the optimisation of information flows [3,4].

1. Informal statement of the problem

The purpose of this chapter is to describe a sequence of DAS modeling using queuing theory. Alarm signals, transmitted by sensors of facilities to DAS in random moments, are presented as a queue [5]. Customer service is performed as analogue digital conversion [6]. This modeling method was selected in order to determine analytical dependence of technical parameters of DAS elements and queuing system indicators. Modeling results allow optimizing amount of structural elements that provides harmonizing output indexes of system and capacity requirements of channels.

Main idea is to model DAS as the queuing system with *n* channels represented by ADCs and the queue limited by *m* SHAs [6].

1. Formalization and analysis of the DAS model
	1. *Construction of network model*

A failure probability of customer service is determined if all *n* ADCs and *m* SHAs are occupied [1,4]:

 , (1)

where is the average arrival rate; is the average service rate of a single service; is the average time of capacitor discharge by free ADC;

 (2)

is the probability that the server is idle (figure 1).

Raw materials extraction points

Point of temporary storage of raw materials

Points of temporary storage of finished products

Shops

Firms producing finished products









Figure 1. Transport network

## Definition of the shortest path matrix between all pairs of points

To obtain this matrix, we use the Floyd algorithm. This algorithm is useful in our case, since we are dealing with a large number of edge pairs between pairs of vertices.

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1. Calculation of the optimal number of DAS elements

In this section, the numerical results of such modeling are presented for those DAS indicators that are used in actual telemetry systems. Table 1 presents the arrival rates  for different ratios of *n* ADCs and *m* SHAs using the failure probability of customer service  and the average time of capacitor discharge  from (1)-(2).

Table 1. Arrival rates  [s-1] at failure probability and the service rate μ=100 [s-1]

|  |  |
| --- | --- |
| SHAs | ADCs |
| n=1 | n=2 | n=3 | n=4 | n=5 | n=6 | n=7 | n=8 | n=9 |
| m=0 | 0.1 | 0.5 | 20 | 45 | 80 | 120 | 160 | 210 | 260 |
| m=1 | 3.5 | 18 | 45 | 75 | 120 | 165 | 210 | 265 | 310 |
| m=2 | 11 | 35 | 65 | 105 | 150 | 200 | 245 | 295 | 355 |
| m=3 | 19 | 49 | 91 | 130 | 180 | 230 | 280 | 335 | 395 |
| m=4 | 28 | 65 | 112 | 160 | 210 | 260 | 320 | 380 | 440 |
| m=5 | 36 | 80 | 130 | 180 | 230 | 290 | 350 | 420 | 470 |
| m=6 | 41 | 90 | 145 | 200 | 260 | 310 | 380 | 450 | 500 |
| m=7 | 48 | 100 | 155 | 220 | 270 | 345 | 400 | 460 | 530 |

1. Conclusion

A model DAS structure that optimizes coordination between the system and output channels in terms of their bit transmission capacities is described. In order to create the DAS model, mathematical methods derived from queuing theory, particularly the M/M/n/m Markov model, are used. Our research is bounded by the study of a schema of a dual-slope ADC, such as is widely used when measuring engineering processes. Future research will focus on DAS modeling using other types of ADCs and dynamic DAS commutation to channels having different capacities.

1. Acknowledgment

The work is partially supported by the RFBR grant # 18-01-00796.

References

[1] Sze S M 1969 *Physics of Semiconductor Devices* (New York: Wiley–Interscience)

[2] Dorman L I 1975 *Variations of Galactic Cosmic Rays* (Moscow: Moscow State University Press) p 103

[3] Caplar R and Kulisic P 1973 *Proc. Int. Conf. on Nuclear Physics (Munich)* vol 1 (Amsterdam: North-Holland/American Elsevier) p 517

[4] Kuhn T 1998 Density matrix theory of coherent ultrafast dynamics *Theory of Transport Properties of Semiconductor Nanostructures* *(Electronic Materials* vol 4*)* ed E Schöll (London: Chapman and Hall) chapter 6 pp 173–214

[5] Strite S and Morkoc H 1992 *J. Vac. Sci. Technol.* B **10** 1237

[6] Nakamura S, Senoh M, Nagahama S, Iwase N, Yamada T, Matsushita T, Kiyoku H and Sugimoto Y 1996 *Japan. J. Appl. Phys.* **35** L74