Universal Sigma-Delta ADC for Intelligent Distributed Instrumentation

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Summary: In this papers the precision single-board, 8 channels, 24 bit sigma-delta ADC with on-line remote reprogramming mode is described. The results of experimental researches of the noise immunity of the developed ADC in real (industrial) measurement conditions are presented. The results of experimental researches of the prototype in the same measurement conditions are also considered.

Keywords: Sigma-Delta ADC, Sensor Signal processing, remote reprogramming.

1. Introduction

The evolution of measuring engineering is resulted in development of the geographically distributed measurement systems. The network based structures are usually used in such systems. These systems are named as distributed sensor networks (DSN) [1, 2]. In the most cases such networks have hierarchical structure. There are used the PC at the high level of this structure, and the multichannel analog to digital converters (ADC) at the low level. These ADC are usually named as Data Acquisition modules (DAQ) [3, 4]. The special demands to DAQ's modules are made. The most important of these demands are: high accuracy in real measurement conditions, universality, flexibility and network properties. The listed above requirements are especially important in adaptive and intelligent DSN. Besides, the price of the whole network and the price of DAQ's modules correspondingly should be minimized. Let us consider the performance of these requirements by DAQ modules of some firms.

2. The analysis of the existent Data Acquisition Systems

The most DAQ's modules include the amplifiers of sensor signals, multiplexers, ADC, DAC, signal processing modules, interface units, etc. Thus the high accuracy of sensor signals conversion to code is provided in most cases, instead of physical quantity conversion to code [5]. It is necessary to note that DAQ modules should provide the high accuracy of the measurement in industrial measurement condition instead of the laboratory measurement condition. But there are a lot of DAQ modules which provide its characteristics only in laboratory measurement condition. This point is especially related to the different noise influence on the measurement result. The experimental researches, presented in this paper, show that a value of common mode rejection of some DAQ's modules can be achieved for a low level of common noise voltage. Though the common mode rejection is necessary to standardize for 500 V emf of common noise voltage [6]. The network DAQ module I-7018 [7] was taken as the prototype because it is based on the same chip (AD771x series) as the developed ADC.

Algorithms of sensors signal processing can not be varied for most DAQ's modules. Such DAQ modules are specialized for measurement of certain sensor signals. The modules which are considered as universal [3,4] allow connecting the different sensors of the same type (different thermocouples for example) or the sensors of different types (thermocouples and RTDs for example). However such DAQ modules convert into a code the sensor signal for the unforeseen type of the sensor. So it's impossible to obtain the value of physical quantity from DAQ module output. Thus the universality of these modules - is limited. The absence of an opportunity of changing the working algorithm significantly complicates the adaptation of algorithms of signal processing to measurement conditions. Therefore widely used DAQ modules do not provide the necessary flexibility in adaptive and intelligent DSN.

The current software data processing is provided by PC or programmable logic controllers in known universal DSNs [3,4]. It demands PC to work in hard real time mode (in relation to process of data acquisition). Such organization of data processing is allowable for simple DSN where the high processing power of the PC exceed essentially the computing complexity of executing algorithms. When the computing complexity of executing algorithms can not be determined in advance (iterative algorithms of data processing, neural networks, fussy logic for example) or the computing complexity exceeds the processing power, it is necessary to enter the additional hardware devices to parallelize the data processing [8, 9]. This problem is urgent especially for multichannel DSNs.

Besides the absence of the software data processing according to the user algorithms (at the level of DAQ modules) leads (i) circulation of the large volumes of raw data in the network; (ii) the response time of the DAQ calls should correspond to the allowable reaction time to the sensor signal. It requires to use the high throughput communication channels and exclude using the Internet like networks because the access time in such networks is not regulated. So the developed of DAQ modules without defects indicated above is the actual task.

3. The structure of the developed universal ADC with remote on-line reprogramming

It is proposed to use the fully current software processing of measurement results directly in DAQ modules according to the user algorithms. The PC should support the measurement network by providing the executing of the routines which are actual at the present time. Also it is necessary to provide the remote on-line reprogramming [10] for high flexibility and universality of the developed sigma-delta ADC (see fig.1). There is used the chip of Sigma-Delta analog-to-digital converter AD7714. One of its input (IN0) is connected to the output of multiplexer MUX. The second input (IN1) of this chip is shorted. The third input (IN2) is connected to reference voltage source REF. The reference voltage source is based on AD780 chip. ADC structure includes also: (i) microcontroller 89C52; (ii) address register RgA; (iii) random access memory RAM; (iv) demultiplexer DC; (v) trigger Tg for control of the operating modes; (vi) serial interface adapter IFA.

The Reset signal is formed after ADC power is on. This signal resets the microcontroller and trigger Tg. The Tg sets the microcontroller into mode of executing of the program from the internal ROM. Program from internal ROM makes (i) initialization of the microcontroller; (ii) serial interface activation; (iii) activation of the AD7714. Also this program sends to the server of the DSN the signal of readiness and request for loading of executing program. The executing program received by serial interface is located in RAM. The microcontroller forms the 1000 code at the input of DC after receiving of the executing program. It allows changing the output of Tg and reset the microcontroller. Such functionality of the Tg brings to changing of microcontroller's operating mode and performing of executing program. It should be noted also that the code and data segments of executing program are located in the same chip. Therefore the software developer should divide these segments at the compilation of the executing program. Such reprogramming can be done during ADC operation. It is necessary to form 1001 code at the input of DC for such reprogramming. This code changes Tg output to power on condition and resets the microcontroller into loading program operating mode.

It is logically to use the modified RS232 [11] interface as a network interface. This modified interface allows creating the two-wire local area network without using of additional network adapters. The RS485 is also accessible in the developed ADC.

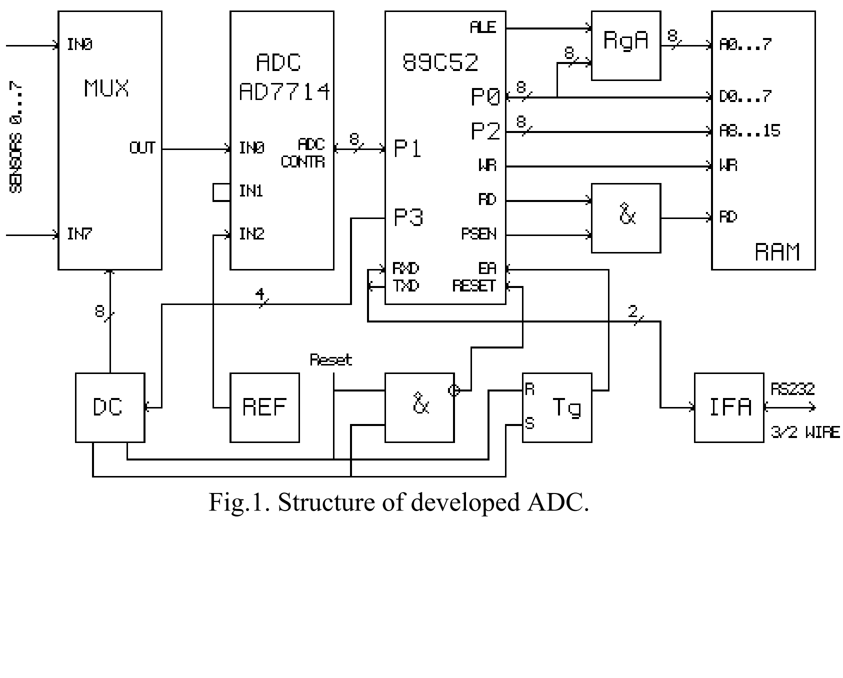

Fig.1. Structure of developed ADC.

Software of the developed ADC consist of the two parts: (i) constant part (drivers of the multiplexer, AD7714 and interface) and variable part (procedures of sensor signal processing, which make the end user algorithms). Therefore each ADC in the measurement network execute the individual version of the software. This software can be changed by the user. The designed software allows using the developed ADC in the existing measurement systems instead the I-7018.

4. The parameters of the developed ADC

Channel number - 8 differential;
Measurement range – ±10…±2500 mV;
Output code capacity – 24 bit;
Maximal error – ±(0,5 + 0,2*Ux) μV;
Normal mode rejection – 100 dB;
Common mode rejection – 160 dB;
Maximal interchannel voltage – 500 V;
Maximal measurement channel to ground voltage – 500 V.

5. Experimental researches

The main difference of the developed ADC from the I-7018 is using of the magnetically operated sealed switches as the multiplexer, shielding case and the power unit with the smaller transfer capacitance (approximately 20 pF). The experimental researches show that this properties significantly increase the common and normal mode rejection of the developed ADC in real (industrial) operating condition. It is actual for high temperature measurement by thermocouples for example.

Fig.2 shows the influence of the common noise voltage of direct current on the measurement error for I-7018 and the developed ADC. Using of the shielding case allow decreasing the influence of such noise on the measurement result to the negligibly small size. The less noise immunity of the I-7018 can be explained by the unsuccessful input balancing bridge circuit.

Fig.3 shows the influence of the industrial frequency common noise (50 Hz) on the measurement results for both ADCs. The unsuccessful input balancing circuit of I-7018 and the large capacitance of the isolation barrier (approximately 100pF) lead to the stepwise change of the common noise immunity of I-7018 in condition of noise voltage more than 20 V. The large value of AD7712's normal-mode rejection can not correct this defect of I-7018. The large value of AD7714's normal-mode rejection can explain the approximate identity of noise error for the developed ADC with or without the shielding case.

Fig.4 and 5 shows the results of the experimental researches of the interchannel voltage of direct and alternating current influence on the measurement error for the developed ADC and I-7018.

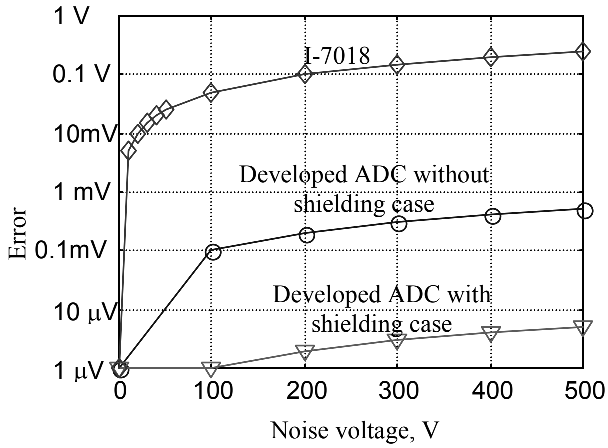

Fig.2 Dependance of the absolute measurement error of the DC common noise voltage

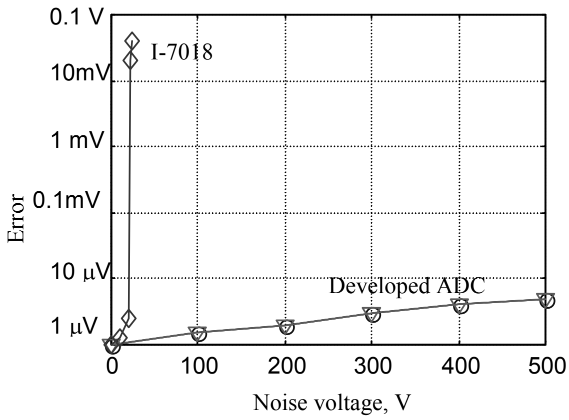

Fig.3 Dependence of the absolute measurement error of the AC common noise voltage

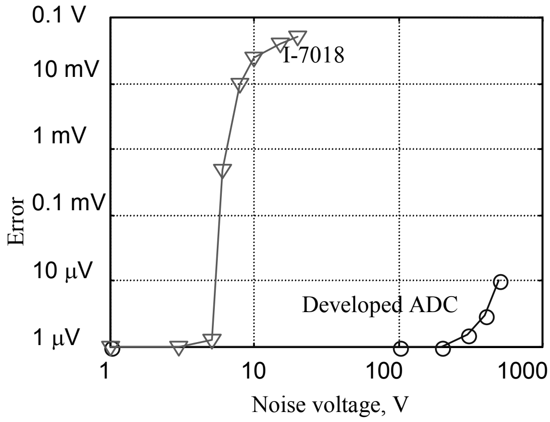

Fig.4 Dependence of the absolute measurement error of the DC interchannel voltage

The stepwise change of the error influence for I-7018 can be explained by using of the electronic multiplexer ADG438 with the ±5 V power voltage. Using of the magnetically operated sealed switches in the developed ADC increase the allowable voltage of the common noise and interchannel voltage. This noise immunity is provided for the 500 V voltage [6]. Therefore the developed ADC allow the precision high temperature measurement.

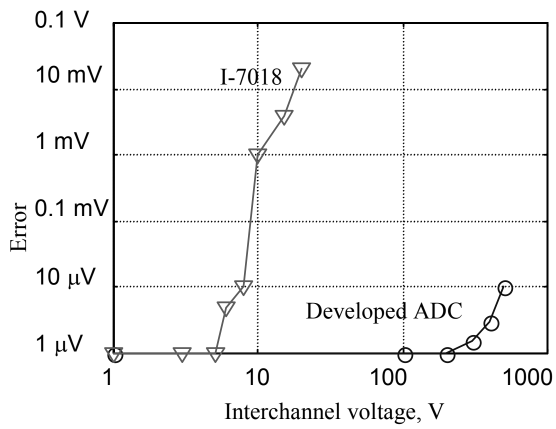

Fig.5 Dependence of the absolute measurement error of the AC interchannel voltage

6. Conclusions

The developed ADC is characterized by high accuracy and noise immunity in real measurement conditions. Software processing of measurement results can allow unloading the local area measurement network as well as the server. It can significantly decrease the price of the network and allow using the network with the not regulated access time, Internet for example. The possibility of remote on-line reprogramming of ADC can provide high universality and flexibility in adaptive and intelligent DSN. These advantages are especially actual for multichannel DSNs.

7. Acknowledgements

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