Modular Multi-channel Data Acquisition Systems

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Abstract—A flexible approach to complexity-reduced multi-channel data acquisition from a large quantity of sensors, essential for connecting computers with real world objects, is discussed and the obtained experience in this area is summarized. Data acquisition from wideband, event timing, and large distributed clusters of signal sources are discussed with emphasis on methods and algorithms providing for data gathering from large sensor systems. We discuss special signal digitizing techniques, including pseudorandomized multiplexing, time-to-digital conversions, and signal sample value-taking at time instants when the input signal crosses a sinusoidal reference function. The versatility of the data acquisition systems is achieved by using modular system design. To achieve the maximum from the suggested data acquisition technology, the acquired data processing is based on the theory of digital alias-free signal processing.

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1. INTRODUCTION

Data acquisition from multiple sources of analog signals is considered in this paper in the context of computer interaction with real world objects. To provide for data gathering and smooth transfer of this information to computers, the involved data acquisition systems have to be sufficiently flexible so that computer links to various types of signal sources can be realized. This means that they should provide for data acquisition from various types of sensors. It helps that outputs of sensors used for converting many different physical quantities into electrical signals are standardized so that a wide variety of physical processes can be observed by analyzing a very narrowed selection of such electrical signal parameters. One sensor output class that covers a very wide field of applications is represented as voltage (current) variations in time. Another wide class of sensor outputs is represented in the time-frequency domain so that the outputs of these sensors are given in the form of a timed appearance of uniform events.

In cases where data acquisition systems are built on the basis of classical digital signal processing, it is not so easy to satisfy these requirements, especially when the data acquisition system under consideration has to provide for obtaining information from a large quantity of signal sources for simultaneous observation of a multitude of processes in parallel. The new emerging digital alias-free signal processing (DASP) technology [1] is much more flexible and, consequently, better suited for developing versatile data acquisition systems appropriate for obtaining information from large sensor systems. This technology and the knowledge accumulated in this area were used to develop the further discussed data acquisition methods, hardware, and software. To acquire data from various types of signal sources and still avoid excessive complication of the system, a modular approach to its design has been chosen. Each of the module types should then represent a specific system for data acquisition and it should be possible to aggregate these modules seamlessly into reconfigurable modular structures that meet the functional requirements of specific applications. In addition, it has been taken into account that it is essential to ensure that the original signals could be digitized close to their sources in order to prevent corruption of analog signals by ambient noise and that the design of the front-end devices should be simple enough to achieve very low power consumption.

To accomplish all that: (1) digital signal representation by sequences of timed events has been selected as the core feature common to all basic particular systems; (2) development of the versatile massive data acquisition system was based on the concept of remote sampling of distributed analog-to-digital conver-

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It is not obvious what this type of analog-to-digital conversions and the digital signal representation by sequences of timed events have in common. Explanations for this follow.

2. EVENT TIMING AS THE CORE OF THE MODULAR MASSIVE DATA ACQUISITION SYSTEM

The functions and specific features of the remote sampling of distributed analog-to-digital converter (ADC) are close to what is needed for the mentioned tasks of data acquisition. Therefore, this system was the basis in developing the considered massive data acquisition system. Analog signal sampling, according to this approach, is rather specific. It is performed as signal sample value-taking at time instants when the input signal crosses a sinusoidal reference function. This approach to signal digitization has already been described and relatively well investigated both theoretically and experimentally. The results are given in [1–5, 16]. Therefore, the basic scheme of this kind of signal digitization is repeated here in Fig. 1 only as a reference. Without this illustration, it would be difficult to understand the essence of the following discussions.

To perform signal digitization according to this scheme (Fig. 1a), the input signal is compared with a sine-wave function serving as a constant-parameter reference function. This signal and reference comparison operation might take place only during the time intervals when the involved comparator is enabled. A special enabling function, given in Fig. 1b, is generated and used for that. Attention is drawn to the fact that enabling of a particular comparator is not necessarily performed periodically. As will be further explained, in specific cases where ADSP has to be realized, the enabling function is nonuniform. Once a comparator is enabled, a short pulse is generated at the output of the comparator whenever a crossing of the signal and the reference function occurs. Therefore, the sequence of these pulses reflects the sine-wave crossings (SWCs), and this sequence of crossing events, shown in Fig. 1c, represents the output signal of this digitization scheme.

In the context of the mentioned distributed ADC, this scheme is considered as a sampler used for obtaining the sample values of the original input signal. As the design of this sampler is very simple, its power consumption might be ultralow and it might be placed in the close vicinity of the respective signal source. Therefore, this type of samplers is well suited for operation at a distance from the central part of the distributed structure of the ADC fulfilling the function of remote sampling. Moreover, its structure makes it easy to perform data acquisition from a large quantity of signal sources and, more importantly, it can be done without switching off the analog input signals. Multi-channel data acquisition is realized by enabling of the comparators used for sampling of the signals in the time sharing mode.

3. MODULES FOR MULTI-CHANNEL ANALOG-TO-EVENT CONVERTERS

Since conditions for data acquisition vary, various types of systems operating on the basis of the described multi-channel data acquisition methods and algorithms have been developed to cover a wide range of applications. Compatibility of these systems was a specific design requirement. Therefore, these systems might be used as embedded systems or modules that can be interconnected into various structures depending on needs of specific customized massive data acquisition systems. A multi-channel versatile data acquisition system is considered, called Module 1.