Experimental Evaluation of Conditions for Short-distance Transmission of Event Timing Data

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***Abstract*—Specifics of event timing data transmission are experimentally investigated under conditions typical for multi-channel data acquisition from a large quantity of signal sources. The events, in the considered case, are analog input signal and sinusoidal reference function crossings. The sequences of the crossing time instants represent the respective analog input signals and these sequences have to be transmitted to the signal reconstruction subsystem. An experimental system for fast short-distance transmission has been built. It performs data encoding on the basis of digital pulse position modulation with 10 picoseconds resolution. The achievable data encoding resolution and other vital parameters characterizing data transmission systems of this type were evaluated on this basis.**

***Index Terms*—Signal processing algorithms, digital signal processing, event, timing, data transmission.**

I. INTRODUCTION

The necessity to perform short-distance transmission of picoseconds-resolution data comes up whenever event timing encoding is used. While the end-result of event timing typically has to be given as a picoseconds-resolution digital quantity, transmission of this information can be performed in two different ways, analog or digital. Both analog and digital information representations are used for event fixing in time and either analog or digital carriers can be used for transmission of this information. And both of these analog and digital information transmission options have their advantages and drawbacks [1]–[6]. The specific conditions for transmitting event timing information are investigated for two typical types of applications, namely, for:

1) Gathering and transmission of data from a cluster of remote samplers to the master part of the respective distributed ADC performed in the process of data acquisition from a large quantity of signal sources [7], [8];
2) High-speed short-distance transmission of digital data by transmitting position-modulated short pulses and information content recovery based on time variable sampling of ADC.

These two cases are considered as generalized models of two types of specific event timing information transmission subsystems. They cover a number of various specific applications in the field of multi-channel data acquisition.

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Short-distance transmission of digital data is in the core of this type of data acquisition systems as these systems actually fulfil functions of a specific multi-channel distributed ADC [7]. Specific signal encoding is used.

This approach to analog signal digitizing has been used before and some of the gained experience in this field is described in [1]–[5]. It is based on detection of analog signal and reference function crossing time instants and the obtained in this way sequence of time instants fully represent digitally the respective analog signal [6]. Using this type of digital signals leads to various benefits, in addition to the possibility of compressing data that are to be transmitted. For instance, alias-free data acquisition from wideband signal sources [9] and complexity-reduced processing of this type of data in the frequency domain can be performed [10], [11].

II. ANALOG REPRESENTATION AND TRANSMISSION OF EVENT TIMING

In the first case the event timing information is given in an analog form and short pulses are used as analog carriers for transmission of this information, as shown in Fig. 1. In the considered case they, specifically, carry the input signal and reference function crossing event timing information form a multitude of front-end devices to the distributed ADC reconstructing and displaying the received information. Outputs of all front-end devices are connected through a single OR logic element to the transmission line.

Using this type of analog information carrier effectively provides for data compression and for increasing the operational speed of the system in this way. Indeed, the transmitted data are compressed because transmission of a single pulse in this case is equivalent to transmission of a multi-bit word. This approach to transmission of the event timing information has been used [3], [4]. As it leads to data compression in a simple way, it is of high practical interest to extend the application area of this method. However to widen its application range, a number of essential problems have to be investigated, in particular, the following:

1) Analog event representation of the respective digital inputs with subsequent digital representations of the respective analog data;

2) Taking into account that the time intervals between timed events are non-uniform and not necessarily random;

3) Specifics of the considered timed event signals having features unparalleled by other types of digital signals.

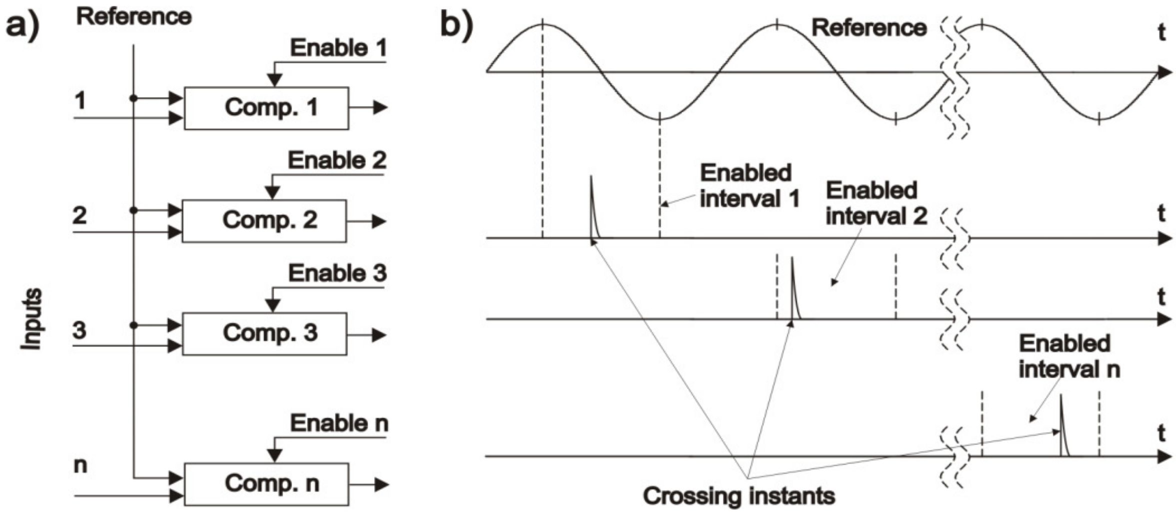

Fig. 1. Typical conditions for gathering and transmission of timed event data from a cluster of remote samplers.

III. Model of Digital Data Transmission

Both computer simulation and experimental studies have been carried out to make these investigations. The basic features of this type of data compression, in particular, for high-speed short-distance transmission of digital data needed for many various applications have been experimentally investigated on the basis of a system having the basic configuration shown in Fig. 2.

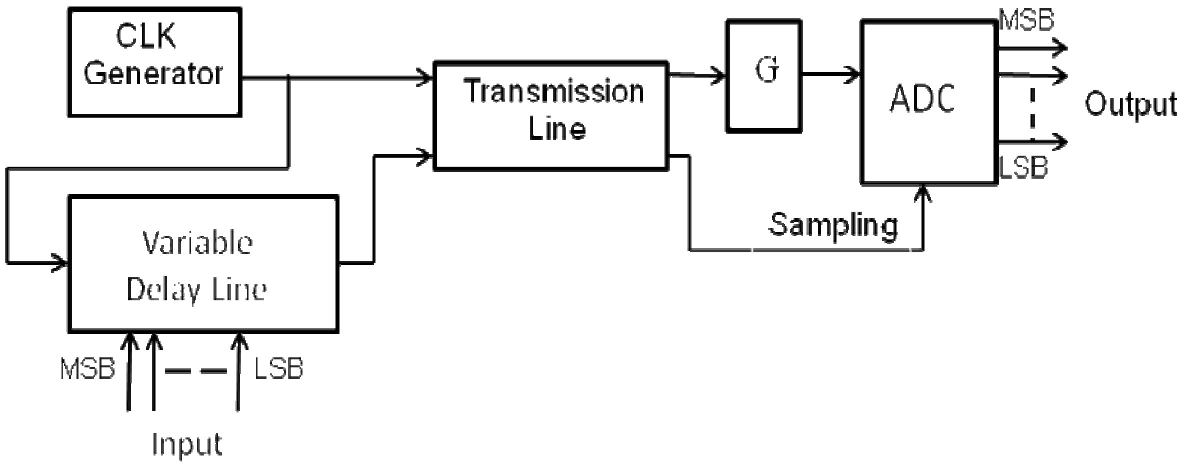

Fig. 2. Model of the considered digital data transmission.

The further described experimental set-up was built in accordance with this principal structure. As can be seen it consists of two parts connected by a transmission line. The first part serves for input signal encoding and the second part performs recovery of the encoded signal received over the transmission line. Both parts are synchronized by a common clock sequence. A variable picoseconds-resolution delay is used for delaying the clock pulses proportionally to the respective input signal values. These variably delayed pulses are used for carrying the input information. They are also initiating sampling of a reference signal put to the input of ADC. The input signal transmitted over the transmission line is reconstructed in this way. While various reference functions could be used, preference is given to sine-waves as it is easy to generate them and to stabilize their parameters, they have extremely simple and well-defined spectra and they are convenient also for reconstruction of the sampled signals. As this structure is used for multi-urpose experimental investigations, the reference signal at the output of the generator G in this case is such sine function.

According to the considered functional structure, the digital carrier of the reconstructed digital input signal (equivalent of event timing information) is formed by the ADC at the stage of transmitted data reconstruction. While this type of signal digital representation is specific and successful using of it requires some skills, it leads to obtaining significant benefits. Specifically:

1) Achieving time and energy saving at data transmission (each single symbol transmits a multi-bit word);

2) Compatibility with the Ultra-wideband wireless data transmission technology;

3) Complexity-reduction of algorithms for data pre-processing.

Whenever this device is used for multi-channel data acquisition according to the principles illustrated by diagrams given in Fig. 1, only those signal-reference crossings are taken into account that happen during the time intervals when the respective comparator is enabled by a specially generated enabling function. This enabling function is also used for executing the input multiplexing. The analog input signal switching is avoided in this way and that certainly represents a significant advantage.

IV. Experimental Evaluation

Diagram of the developed and made experimental set -up is given in Fig. 3. It is connected to a computer so that input and output data sequences could be monitored and analyzed.

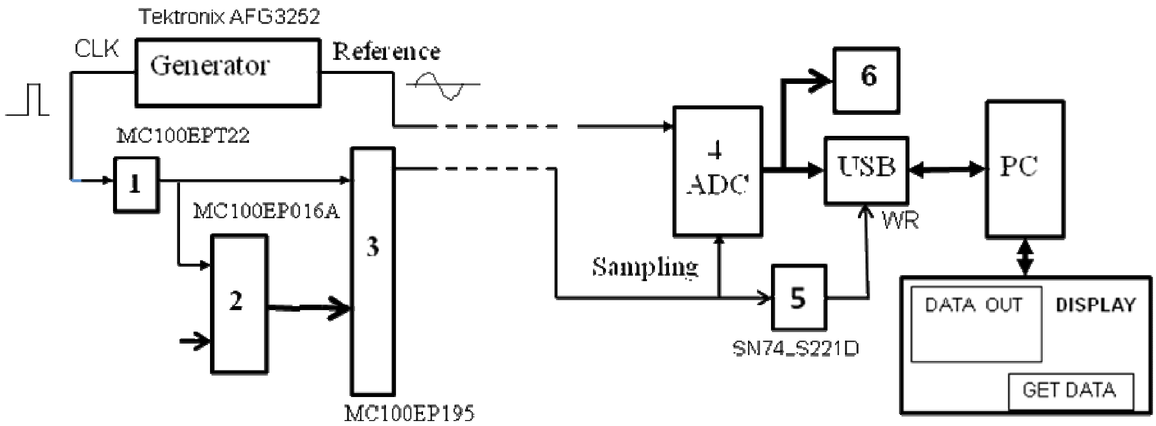

Fig. 3. Experimental set-up: 1 – TTL/PECL translator; 2 – binary counter; 3 – variable delay line; 4 – ADC; 5 – write pulse former; 6 – LED display.

The experiments were carried out to evaluate the achievable resolution of pulse position modulation performed on the basis of the controllable digital delay line. The upper frequency of the reference sine wave depends on this parameter as well as on the bit number in the transmitted binary words. The upper limits for the transmitted data bit rate and transmission speed in this case actually were imposed by the interface between the experimental set-up and PC.

Experiments were carried out under the following conditions:

1) The used delay line was programmed by 10 bit parallel code;

2) 12- bit parallel output ADC has been used with the upper limit of the dynamic range equal to 5 V_{pp};

3) Maximal voltage LSB increment 1,22 mV;

4) To limit the time interval of variable ADC sampling, the highest used reference signal frequency was 24 MHz;

5) Phase angle adjustment between clock and reference signals was used.

The experiments carried out were aimed to finding: (1) potentially weak spots in interaction of separate parts of the system and to finding (2) what is the smallest value of sampling pulse delay that would ensure a stable change in the ADC output code at least for 1 bit and how this smallest value depends on the used reference signal frequency. The targeted results were achieved, as it is explained in the following conclusions.

The first part of the experiments, covering tests of various options in supporting the functionality of the system, involved even some changes in pulse shaping and in supporting of synchronization. Some changes in design were made also to suppress the system`s sensitivity to external and power supply noise. Detailed description of this first part of experiments is out of the scope of this paper.

The second part of the experiments, specifically, experiments repeated under variable conditions to reveal the basic properties of the system, showed that a shift in pulse position for 10 picoseconds provides for stable transmission of a single bit increment. Actually this time interval does not represent the smallest achievable shift in pulse position providing for transmission of a single bit. This parameter clearly depends on the quality of the system design and significant improvement in evaluated parameters could be expected if this system is implemented on a higher level of microelectronic element integration.

V. Conclusions

The carried out experimental studies confirmed that the used approach to short-distance transmission of timed event data makes it possible to achieve at least 10 picosecond resolution at pulse position modulation using 24 MHz reference sine wave. Data transmission under these conditions was stable even for circuit designs based on a PCB and available IC chips. These parameters are acceptable for multi-channel data acquisition implementation in a wide application range. However it is also clear that the obtained experimental results do not represent the currently achievable limit. These experiments also revealed where the bottlenecks in data transmission systems of this type are. Thus these experimental studies provided the targeted results and analysis of them shows how to improve microelectronic implementation of the considered timed event data transmission.

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