A Proposal For Rapid Prototyping System For Data Acquisition Devices

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Abstract - **The paper describes a proposal for rapid prototyping system for data acquisition devices based on FPGA and micro controller. It also describes a realization of the system for acquisition of IRIG-106 data, based on proposed approach.**

Keywords – **Data acquisition,microcontroller, FPGA, IGIR-106**

I. INTRODUCTION

Data acquisition system is the system developed to measure and log the data with the objective to improve or maintain the object of measurement. In the recent decades, the development of computers caused the modification of acquisition systems architecture. Two parts can be clearly distinguished in these systems: hardware and software architecture. Hardware is divided into sensors, physical connections and electronic components, while the software architecture contains the common and the application-specific program segments. This paper shall not take the sensors and physical connections into consideration. Electronic components should provide the reliability of the system at the physical level and easy system organization, since they provide the hiding of functioning details and simple interfacing towards the user. Software design include development of embedded programs for microcontrollers and for FPGA devices (*Field-Programmable Gate Array*). In addition, a set of program tools is required for data processing and analysis on the desktop computers. Common part of the code is designed to support basic functions of acquisition system, mutual for the each of its possible implementation. Application code is specific for individual implementation (application of generalized solution).

This paper describes a proposal of acquisition system for which the following objectives have been put forward before designing:

- modularity
- portability between various platforms
- simple adaptation of the system to the various standard forms of input data (reconfigurability)
- simple maintenance and easy training of the user
- standardized data output form.

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II. SYSTEM DESCRIPTION

A. *Input Data Flow*

Figure 1 shows the flow of the input data through the segments of the proposed acquisition system [1].

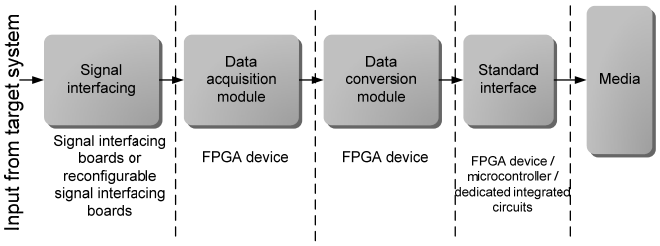

Figure 1. Input data flow trough the data acquisition system

The signals from the sensors are to be adapted first, in order to be used later in the system residue. This is carried out by means of specialized signal interface board, having the special-purpose and standardized I/O ports. First are used for connecting to the source system, while the other transfer adjusted input data to the rest of the acquisition system. Following step is the sampling of the input stream, i.e. acquisition of the input signals and their conversion into the standardized format. Finally, data are transferred to a storage media, using one (or some) of the standard storage interfaces implemented within the system.

B. Signal Interface Board

Signal interface board may be developed to correspond to one target measurement system only, or to be configurable, i.e. to be used for several types of signalization. In case that interface boards are developed to correspond to one target system only, it is necessary to modify them when moving to the system with the different signal characteristics. The adjustment of configurable interface boards can be done by means of switching elements, or it may be automatically recognized which of the target systems is coupled and then configure signal interface module for the recognized system. During the development of acquisition system conception, several electric schematics were developed for the certain number of configurable interface boards which cover the most prevailing types of signalization.

C. Data Acquisition and Conversion Into The Standardized Data Format

This segment of input data processing is specific for each measurement data standard or the group of standards, and requires their knowledge in details. In the whole system only these two segments must be specially written according to each standard separately. The format of standardized data is selected to be as simple as possible for easier conversion of the acquired data, and more general one in order to be able to cover the larger group of various input data formats [2].

D. Storage Interfaces and Medias

To design and realize the acquisition system for the specific standard and specific requirements of the users within the shortest possible time, all types of the most used storage interfaces have been developed in advance, and tested in practice. Actually, they are: USB, UART, interfaces for memories type SDRAM, DDR SDRAM, DDR2 SDRAM and SRAM, Parallel ATA interface, some of interfaces to permanent FLASH memories and memory cards like CF and MMC type. By simple selection of modules, some of which are realized in FPGA devices, and some in microcontroller, and by their linking up with specific media it is easy to design the desirable storage media. This approach enables the redundancy of logging acquired data both on media of the same type and on various media. It is also possible to select the interface and the media with sufficiently large data capacity or transfer rate, so that all acquired data could be saved in safe way.

E. Output data flow

Figure 2 shows the output data flow block diagram of the proposed acquisition system, as well as the way of implementation of each segment of output data flow.

After the phase of data acquisition, it follows the phase of data processing and analyzing of the collected data. The first step in this phase is to transmit the collected data to the desktop computer. If a media to which the data are saved is removable, this operation is reduced to media takeover, location into the media reader connected with the computer

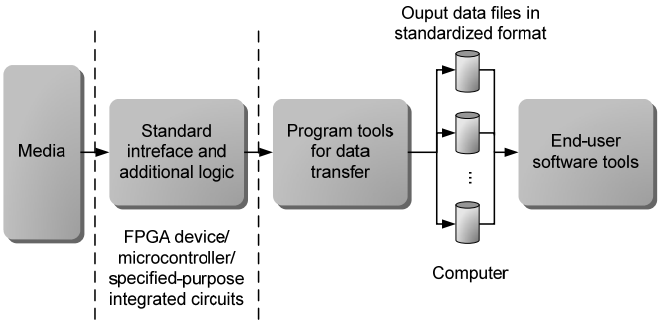

Figure 2. Output data flow block diagram of data acquisition system

and data takeover. If a media to which the data are saved is not removable, then it is necessary to connect the acquisition system and the desktop computer via some of the implemented standard interfaces, and commence the transfer of data to the computer. Many of the related interfaces are not directly accessible to the computer and, in this case the data saved to the media are to be read via an intermediate coupling. For example, data was saved into the memory of DDR RAM type, ant it was planned to use USB for data transmission to the computer. In this case the intermediate module is used, realized inside FPGA device, whose task is to read the data from DDR RAM memory and transmit them to microcontroller, which then transmits them to the computer via USB coupling. The intermediate modules which enable the most of the combinations of implemented storage medias and output interfaces.

The task of the special-purpose program tools, running on desktop computer, is to takeover the collected data correctly, to check their validity at the level of standardized data format, and to compile the data from the standardized data format into the standardized data file format. For data takeover, this tools use some of standard interfaces available at desktop computers. The result of takeover operation is the set of data files, whose format is standardized, explained in details and clearly presented to the user who takes such data files as an input for further processing and analysis. This round up the complete cycle of data acquisition and processing.

III. Analysis Of A Proposed Acquisition System

This chapter will contemplate whether and to which extent a proposed system conforms to the objectives put forward in introductory chapter.

A. Modularity

After the definition of requirements for the realization of the particular acquisition system, next step is the selection of the relevant modules from the set of beforehand developed and tested modules, and the realization of modules for data acquisition and conversion into the standardized data format. For the realization of the special-purpose modules it is necessary to get acquainted with the actual data format and related standards. Another reason for this is the procurement of a signal interface board, adapted to the actual set of input signals. It can be found in the set of beforehand realized interface boards, or it has to be developed from the scratch.

On-board FPGA device plays an essential role in the system modularity. Application specific modules, like modules for data acquisition and conversion, and modules that implement various storage and communication interfaces, are realized mostly in FPGA. This enables the digital system inside the FPGA device to be simply realized, by linking these modules with the implemented interfaces defined in advance. All this modules and interfaces, well-tested and interconnectable in standardized way, give the whole system very high degree of modularity. Modularity enables rapid, simple and safe realization of an actual acquisition system.

B. Portability

The portability between the platforms implies that a code both for FPGA and microcontrollers is realized to be as common as possible, resp. to be less dependable on the platform (architecture) [3]. FPGA code is not written to use primitives of a particular manufacturer or FPGA device series, or directives and types characteristically for certain compilers. In some cases it results in non-optimal digital systems inside FPGA device, but on the other hand, it does not introduce the limitations into the selection of manufactures or FPGA device family, as well as the compiler being used.

Code for microcontroller is written in high programming languages with the emphasis placed on portability between the groups of the most prevailing architectures in the market.

This approach of writing the codes for FPGA and microcontroller provides the portability between the various existing standard platforms and development environments, as well as conformability to fully specialized and special-purpose platforms.

C. Reconfigurability

In the preceding chapters it was mentioned that the non-standard components in the system are realized inside FPGA device. By this it is enabled to make use of one of the most essential features of FPGA device, reconfigurability. By simple modification of FPGA device configuration code it is possible, within the very short time period, to obtain fully different functionality of the complete system. For example, it is necessary to takeover the data from three fully different measurement systems. All three configurations of FPGA device can be saved into the permanent memory of acquisition device and the desired configuration selected by the switch, i.e. the data are collected from another measurement system. At the same time, microcontroller obtains the information on the type of measurements from the same switches serving for selection of FPGA configuration, or directly from FPGA, in the case that configurable signal interface is used and that the digital system inside FPGA contains the module which may detect which measurement system is instantaneously active. By modifying the contents of FPGA code and by informing the microcontroller on the type of system from which the data are taken over, all necessary data flows are adjusted for the valid logging of the accepted data. Even in case that it is necessary to use the completely different media or interfaces for each of the supported options, the system developed in such a way may conform to the requirements.

D. Simple Maintenance Of The Device and Easy Training Of The User

The device is developed in such a way that only basic or no maintenance is required. This can be achieved by careful designing of the housing , electric and electrostatic protection of the device, automatic elements requiring minimum servicing and comprehensive testing of each device unit.

From the standpoint of the user, the maintenance of the device is reduced only to periodical taking care of acquisition device batteries, in case that the device contains the media which might lose their contents after the supply switching off.

For the sake of simplicity, safety and simplification of the user's training, the interaction of the end user with the acquisition device is minimized. There are some program tools with minimal and easy-to-understand GUI, there are few switches and a display installed inside the acquisition device, and there is a terminal block for physical connection to the measurement system. The anticipated simple and safe handling procedures are also very essential for easy use of the actual system and the rapid training of the end user. The role of the specialized program tools is very important here, because it enables simple and standardized use of the system disregarding which media or interfaces are used. The user has no need to know neither the architecture of the system, nor the details of the interfacing with the device. The interaction with the user in is performed at the level of taking over the saved results.

E. Standardized Data Output Form

In addition to the saved data takeover, the task of the special-purpose program tools is to log the taken data into the data files of the pre-defined and standardized format. In this way the user is capable of developing the application programs for processing and analyzing of the collected data.

IV. Overview Of Realized System For Data Acceptance According To IRIG-106 Standard

This chapter contains the description of an acquisition system, realized by using the methodology described above. The acquisition system should collect the data from the target PCM measurement system based on IRIG-106 (*Inter Range Instrumentation Group*) standard. Figure 3 shows the input data flow of acquisition system according to IRIG-106 standard.

The target system for signalization uses the standard TTL voltage levels, which for the requirements of acquisition system, are to be converted to CMOS low-voltage levels. TTL and low-voltage CMOS signalization are frequently used and for that reason the signal interface board for conversion from one to another voltage standard is pre-developed. It was necessary to scale the existing solution only in order to support the required number of signals.

The next step is the data acquisition. For more simple and more reliable acquisition of IRIG-106 data, it has been decided that the acquisition is not based on frames and sub-frames prescribed by IRIG-106 standard, but on words which are the building-block units of frames and sub-frames. By this approach one configuration of the device can cover all possible variants of frame and sub-frame sizes for the particular data transfer rate. In another words, the acceptance is not sensitive to the mode of data formatting into the frames

and sub-frames and enables their size to be modified during the operation without data loss.

The available data transfer rates are: 128, 512, 1024, 2048, 4096 and 8192 13-bit words per second. If the concept of the acquisition system previously explained would be followed, it would be necessary to develop the special configuration of the

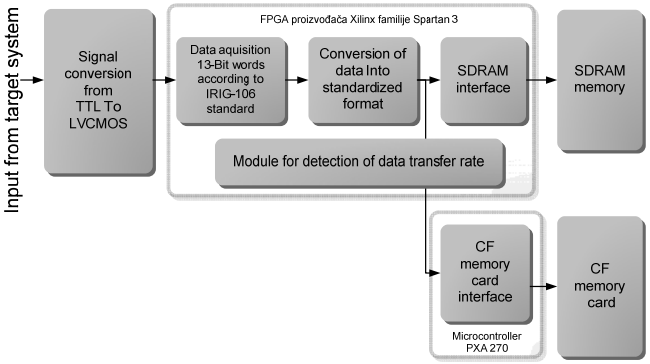

Figure 3. Input data flow of acquisition system according to IRIG-106 standard

system for each data transfer rate. To reduce the number of system configurations to a minimum, it is possible to make use of the fact that IRIG-106 standard prescribes the data transfer rates in ratio $1:2^n$ where n =2,3,4,5 and 6, in relation to the highest data transfer rate. This fact is utilized by adding the specialized module in the digital system inside FPGA device, whose task is to detect the data transfer rate prior to the beginning of data acquisition, and to adjust the parameters of other modules in the system for the detected data transfer rate. In this way, instead of six system configurations with slight difference among them, only one configuration is used. This example clearly shows how the reconfigurable logic, in this case FPGA device, creates the possibilities for adaptation of generally set system conception to the actual application.

When the data are acquired and converted into the standardized form, they are sent simultaneously to interfaces to SDRAM memory and to CF memory card. The interface to SDRAM memory was realized in FPGA device, while the coupling to CF memory card was realized within microcontroller. Peripheral interface of PXA270 microcontroller to CF memory card is one of the basic and as such easy to use and very reliable. The reason for realization of SDRAM interface in FPGA device, instead of using the specialized integrated device or microcontroller, is in the plan that the data saved into SDRAM memory are transmitted to the desktop computer by means of USB. The special cross-over module realized in FPGA is used for the transfer of data from SDRAM to USB subsystem. The input data flow is completed by saving acquisition data to the media.

Apart from already mentioned adaptation module, the output data flow coincides with the outlined conception of the acquisition system.

The testing of the realized acquisition system was made in three phases. The first phase included the comprehensive checks of the system data flow in laboratory conditions. The specified-purpose signal generator was developed to automatize the system testing process and to enable the complete control of the input signals. For this purpose was used the existing system for rapid development of digital system prototypes.By controlling the signal generator and using UART serial connection, on the same computer to which the data are taken over from the acquisition system, the device of device testing is closed. The result of the first testing phase showed that all data sent by the signal generator were

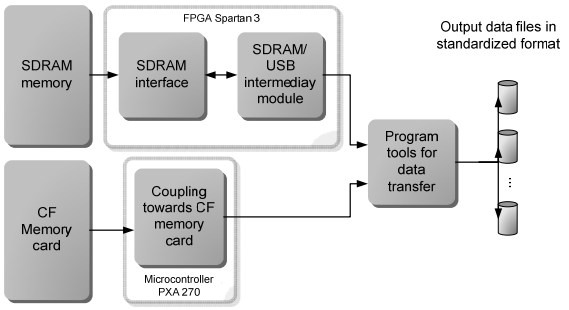

Figure 4. Output data flow of acquisition system according to IRIG-106 standard

correctly accepted, logged and transferred to the computer, i.e. the functionality of the acquisition system was confirmed. The second testing phase comprised the laboratory check of acquisition system behavior in all conditions for which it has been estimated that they may appear in practice. This testing phase was carried out by the specialized testing institution. The results of all checks of the second phase were fully satisfactory what made the beginning of the third testing phase possible. The last testing phase includes the long-term tests in actual use and during the writing of this paper was still in progress.

V. CONCLUSION

The paper describes a proposal for data acquisition system based on FPGA device and microcontroller. All objectives put forward in front of the system before designing are fulfilled to larger or smaller extent. An example of acquisition system realization for data acceptance according to IRIG-106 standard showed that the proposed conception is justified, but at the same time that a lot of space is still left for the expansion and improvement. First of all, a set of supported options for signal interfacing, storage medias and desktop connections are to be expanded. One of the possible expansions of the concept is to enable the acquisition of several data flows based on various standards at the same time, and their later synchronization by the software.

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