Reduced Data Sample Transmission – Implementation to PIC Microcontroller

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Abstract – **In this paper, an implementation of simple adaptive sampling algorithm to the general purpose microcontroller is presented. Algorithm is based on the multi-resolution signal analysis using Haar wavelet. As a target system Microchip PIC 16F877A microcontroller on a single chip is used. The algorithm for signal acquisition and adaptive sampling is deployed to the microcontroller's flesh memory and tested. Possible applications are explored and studied.**

Keywords – **Discrete Wavelet Transform, Microcontrollers.**

I. Introduction

The principal problems of signal analysis are analogue signal sampling and their reconstruction (or approximation) on basis of their discrete samples. In the conventional distributed autonomous measuring systems, the common practice is based on the Nyquist sampling theory. This means that the measured signals are converted to the series of equally spaced samples, preprocessed in the distributed measuring system, and passed to the host computer via a serial channel for collecting, storing and for further processing [1].

The available storage capacity and the energy consumption of the distributed measuring systems in some cases are primarily limiting factors [2], which motivate to develop new algorithms based on adaptive sampling [3], and/or sampling and transmission of samples only at instances of time when the signals exhibit nonlinear changes of the slope. The last means reduction of the number of transmitted samples in Nyquist sense, but sufficient for the satisfactory signal reconstruction.

In the paper we propose a design of a system which transmits a subset of the regularly sampled signals, on basis of which the original signal could be satisfactorily reconstructed..

Section II presents theoretical background and basic idea for reduced data transmission. Section III describes the target system for algorithm implementation and section IV graphically presents experimental results.

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II. Theoretical Background

A .Wavelet Packets

Time localization at high frequencies can be enhanced by wavelet packets decomposition. Here approximations as well as detail coefficients are successively decomposed by Mallat's algorithm creating a binary decomposition tree. Each leaf corresponds to a certain frequency. In the orthogonal wavelet decomposition the information lost between successive approximation is captured in the detail coefficients; successive details are never reanalyzed. In the case of wavelet packets each detail coefficient vector is decomposed in two parts using the same approach as in approximation vector splitting (Fig. 1) which offer the richest analysis.

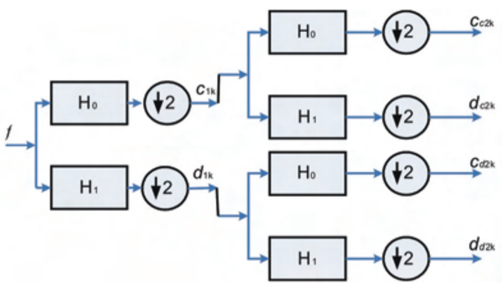

Fig. 1. Wavelet packet decomposition tree.

B. The Adaptive Signal Transmission

The idea of adaptive signal transmission is to transmit only the samples (of the regularly sampled signal) at the instances where the signal exhibits nonlinear changes. Hence the transmitted signal $\mathbf{y}=[y_0\ y_1...\ y_{P-1}]^T$, is composed from the samples of the uniformly sampled signal $\mathbf{x} = [x_0\ x_1...\ x_{N-1}]^T$ by omitting samples with indexes that correspond to instances of linear changing of the analogue signal. Although the size of $\mathbf{y}$ is les than the size of $\mathbf{x}$ (P<N), The analogue signal could be satisfactorily reconstructed by using first order hold circuit.

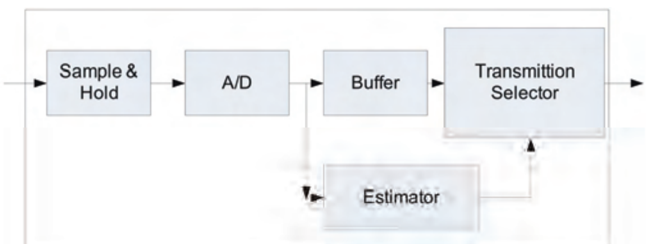

Fig. 2. Adaptive sampling block diagram

The basic idea is illustrated via the following example. A uniformly sampled signal composed of 32 samples is shown in Fig. 3a.

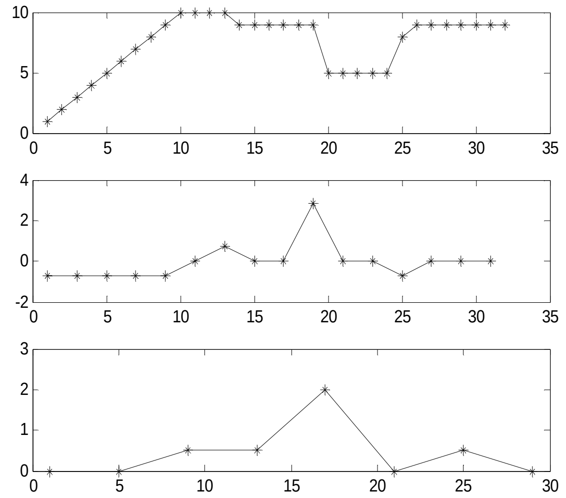

Fig. 3. a)Signal used for algorithm explanation; b) Detail coefficients of DWT; c) Absolute values of detail coefficients of DWT of previously obtained details.

Detail coefficients obtained as a result of discrete Haar wavelet transform of the original signal represent the difference between two successive samples multiplied by a factor of $2^{-1/2}$ (Fig. 3.b).

If the successive samples belong to a linear function the detail result will be a constant. At the second step of decomposition of details coefficients, the two successive constant coefficients will generate zero value coefficients, Fig. 3.c. This leads to the idea, that the decomposition of detail coefficients represents could be used to determine the instances when the transmission of the samples should occur.

The lower the absolute value of the detail coefficients at the second stage of the discrete Haar wavelet transform of the detail coefficients correspond to lower transmission rate of the signal and vice versa..

III. TARGET SYSTEM DESCRIPTION

A. Basic Characteristics of PIC16F877A

In this section we describe the basic features of the microcontroller used for our experiment and the parts of the controller which play the most important rule in this work[4].

Microcontroller basic core features are:

- High Performance RISC CPU
- 35 single word instruction set
- All; single cycle instructions except for program branches which are two cycles
- Operating speed DC – 200ns instruction cycle
- Up to 8k x 14 words of Program Memory
- Up to 368 x 8 bytes of data Memory (RAM)
- Up to 256 x 8 bytes of EEPROM data Memory
- 10 bit multi-channel Analog to Digital (A/D) converter
- Universal Synchronous Asynchronous Receiver Transmitter (USART)

It is important to refer to the fact that the smaller microcontrollers in the same family have the same instruction set. This can be an advantage to contribute to the portability of the source code.

The Analog-to-Digital (A/D) Converter module has eight multiplexed inputs for PIC 16F877A microcontroller, out of which we use only one for the experiment.

Fig. 4 shows an analog input model.

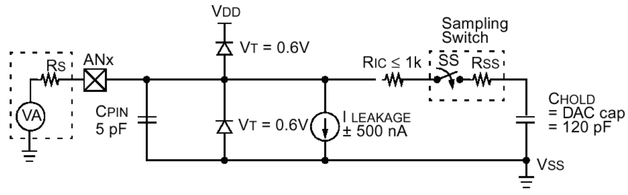

Fig 4. Analog input model.

The A/D conversion as result of successive approximation of the analog input signal corresponds to 10 bit digital number.

The acquisition time which is important to determine the upper sampling frequency can be calculated by the following expressions:

$$\begin{aligned} T_{ACQ} &= (AmplifierSettingTime) + \\ &\quad (HoldCapacitorChargingTime) + \\ &\quad (TemperatureCoefficient) \\ T_{ACQ} &= 2\,\mu s + \\ &\quad 16.47\,\mu s + \\ &\quad \left[(50\,^{\circ}C - 25 \times C)(0.05\,\mu s/^{\circ}C)\right] = 19.72\,\mu s \end{aligned} \qquad (2)$$

The A/D Conversion time per bit is defined as T_{AD}. The A/D conversion requires a minimum $12T_{AD}$ per 10 bit conversion. In our case the internal RC oscillator is used and the typical T_{AD} time is 4μs.[4]

B. Experimental system

The schematic diagram of the input circuitry is presented in Fig. 5. Sensor - potentiometer produce DC voltage signal depending of the measured value. That signal is sent to the microcontroller analog pin for A/D conversion.

Signal generated by the sensor circuit , is in the range of [0 - 5 VDC], and is delivered to the PIC analog port for further A/D conversion. After performing a double level decomposition i.e. discrete wavelet transform, through the High-Pass filtering and down-sampling, transmitting rate estimation and the resulted non-uniformly, adaptive sampled signal is transmitted to the PC for further observing using serial communication port which is supported by the microcontroller hardware and RS232 level converter.

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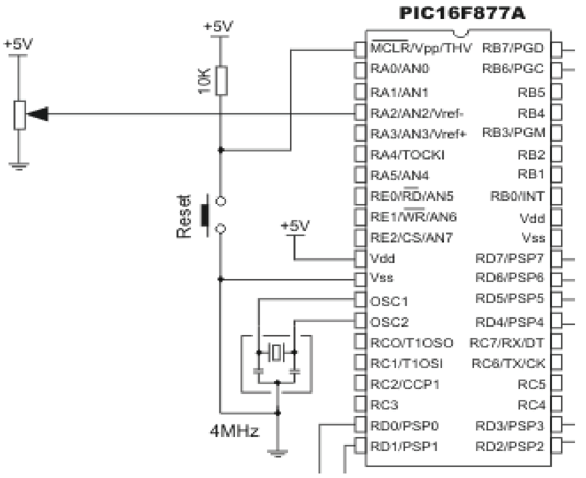

Fig. 5. Schematic Diagram for A/D conversion.

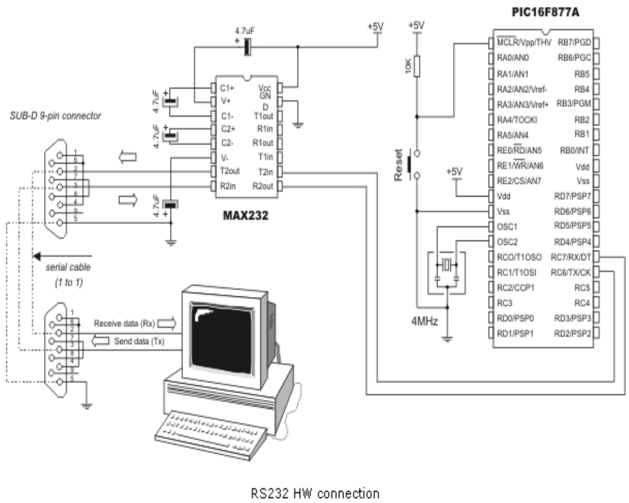

Fig. 6. Schematic Diagram for serial communication.

The system for serial communication is depicted in Fig. 6.

C. The Implemented Algorithm

Program downloaded to the microcontroller non-volatile memory consist of three integral parts as follows: Signal acquiring, where analog signal is converted to digital form and storage the sequence to microcontroller’s RAM; Signal processing, where a two successive Haar Discrete Wavelet Transforms are performed, and transmission rate determining according to obtained results; Signal transmission through serial communication port.

The next block diagram graphically describes the Implemented algorithm with enhanced details to second part mentioned above.

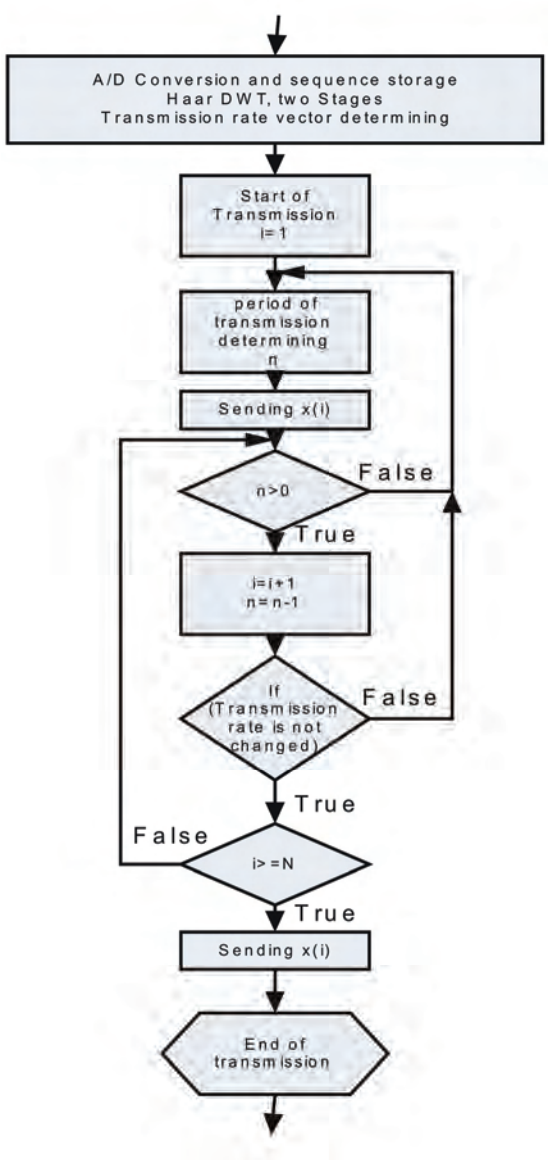

Fig. 7. Block diagram of proposed algorithm

IV. EXPERIMENTAL RESULTS

Analog signal generated by the sensor is uniformly sampled and stored into the microcontroller’s RAM. Fig.8 shows 64 bits uniformly sampled signal acquired by the microcontroller. That signal is sent to the host computer for further comparison with reconstructed signal in the latter phase of experiment.

Due to the small amount of storage, only the detail coefficients are calculated in the first stage of discrete Haar wavelet transform (Fig. 9). The further processing and the estimation of the instances at which the samples are permitted (prevented) to be transmitted require another Haar discrete wavelet transform performed to the detail coefficients, as illustrated in Fig. 10.

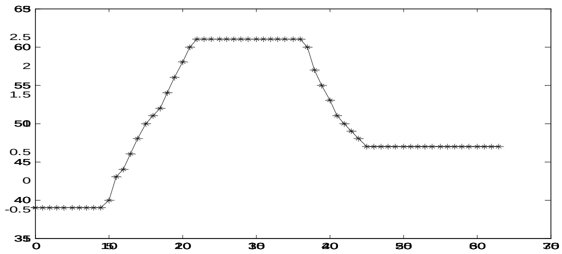

Fig. 8. Uniformly sampled signal generated by the sensor

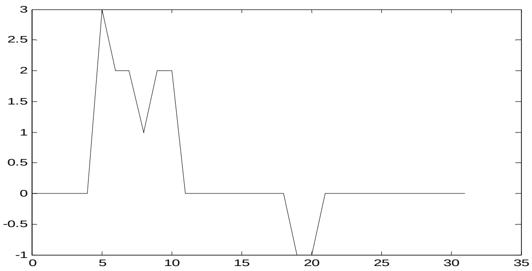

Fig. 9. Detail coefficients of DWT

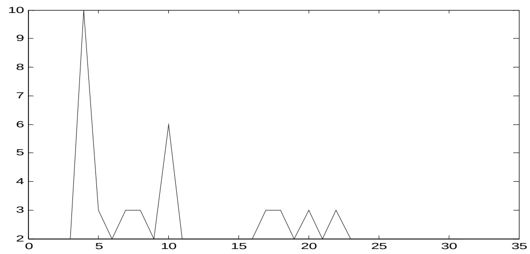

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Fig. 10. Absolute value of second stage DWT coefficients

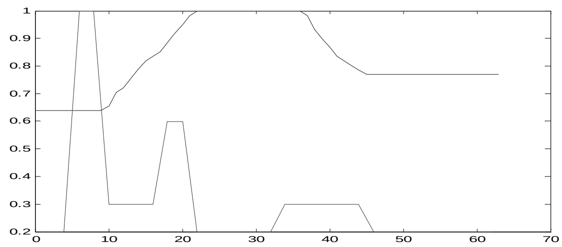

Fig. 11. Transmission rate estimation

According to results illustrated in Fig.11, the transmission rate is estimated. The higher values correspond to shorter sampling period and vise versa. The samples of the transmitted signal are shown in Fig. 12.

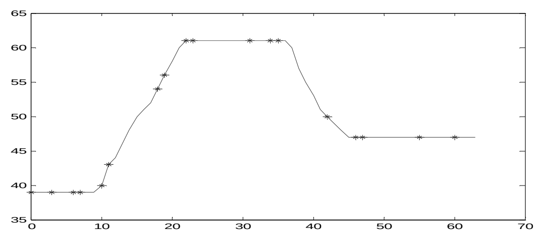

Fig. 12. Adaptive transmitted signal (asterisk) and original signal (solid line)

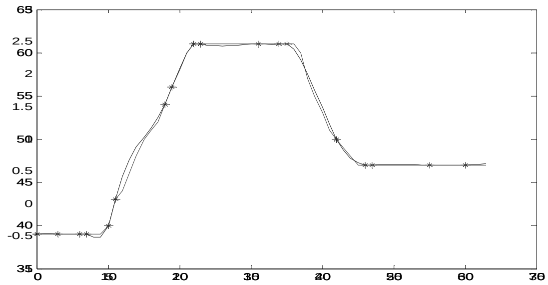

Fig. 13. Reconstructed and original signal

On basis of the transmitted samples the analogue signal could be reconstructed in the host computer either by using first order hold circuit, or by using more complex algorithms for interpolation, such as cubic spline, illustrated in Fig. 13.

V. Conclusion

Experimental results shows that the adaptive sampling algorithm is not complex for implementation to the PIC microcontroller. Small storage resources can be exceeded using the same memory locations for the different stages of discrete wavelet transforms.

Possible applications could be extended to wireless sensor subsystems where the reduced number of transmitted samples solution have great impact on energy consumption.

VI. References

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