12th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2008, Istanbul, Turkey, 26-30 August, 2008

SOFTWARE ENVIRONMENT FOR FREQUENCY ANALYSIS OF AUDIO SIGNALS USING ADVANTECH PCI-1716 DAQ CARD

Petr Dostálek; Vladimír Vašek; Aleš Doležal
Tomas Bata University in Zlin, Faculty of Applied Informatics
Nad Stráněmi 4511, 760 05 Zlín
Czech Republic

ABSTRACT
This paper presents possibility of utilization of Advantech PCI-1716 data acquisition card in system for audio signal frequency analysis. Developed software environment provides extended functionality such as window function selection (rectangular, triangular, Hamming, Hanning and Blackman) and window overlapping. Analyzed signals can be visualized in graphical form in the main window of the program or saved to a file for further evaluation. Measured sound signals are saved to the standard wav files in case of need. Software was created in MS Visual Studio 2005 with utilization of FFTW library which is distributed under GPL license.
Keywords: Advantech PCI-1716, frequency analysis, window functions, FFTW library

1. INTRODUCTION
Frequency analysis is one of the very important tasks of digital signal processing which is today dynamically expanding discipline. It is useful in wide range of applications such as communication systems, medical investigation instruments, multimedia (picture, audio and video processing), military (radar, sonar) and many others. This expansion occurred due to computer technology development which started in the nineties of the last century when these technologies became available for public sphere. Very important role in this area have digital signal processors enabling fast and energy efficient operation.
This work is focused on analysis of audio signals which together with audio compression, voice communication and speech synthesis and recognition belong to field called audio processing. For example, frequency analysis of the rotating bearing can determine its mechanical condition without expensive and time-consuming disassembly. On the similar basis works voice recognition where frequency spectra of the short part of audio signal are compared with known samples and consequently evaluated. Audio compression is based on removal of frequency components which are for human ears imperceptible due to presence of near dominant frequency component. All mentioned applications are based on signal decomposition into sinusoids using Fourier Transformation named after French mathematician and physicist Jean Baptiste Joseph Fourier (1768-1830) [3]. For digital computers and digital signal processors is suitable Discrete Fourier Transform because they can work only with discrete information with finite length. If window functions for demanded analyzed signal modifications are used then we speak about Short Time Fourier Transform.
This paper proposes possibility of utilization of Advantech PCI-1716 data acquisition card for audio signal frequency analysis which can be advantageously used for laboratory measurements because these cards are very often presented in laboratory computers on many technical universities. Main objective was to develop program environment fulfils following requirements:

- Selectable window function type and length in samples
- Adjustable window overlapping in percents
- Visualization of frequency spectra
- Possibility of measured signal storing to standard wav files

2. HARDWARE OVERVIEW

Evaluation system is based on standard personal computer with processor AMD Athlon64 equipped with multifunction data acquisition card Advantech PCI-1716 dedicated for PCI bus interface with full plug and play capability. This card provides sixteen analog inputs in single-ended or eight analog inputs in differential mode with input impedance of 100MΩ. Each input is through analog multiplexor connected to analog-to-digital converter with 16-bit resolution and maximum sampling rate equal to 250 kHz. Integrated FIFO memory with capacity of 1024 samples enables efficient data transfer from the card to the system memory without excessive CPU utilization. It is also equipped with two analog outputs, sixteen digital inputs and outputs with TTL compatible logic and finally with 16-bit timer with reference frequency of 10 MHz [1].

Input voltage ranges are fully software programmable in ranges shown in table 1. Connection with measured object is realized via universal screw terminal module ADAM-3968 suitable for DIN rail mounting. Data acquisition card is connected with ADAM module using 68-pin SCSI-II cable PCL-10168-1.

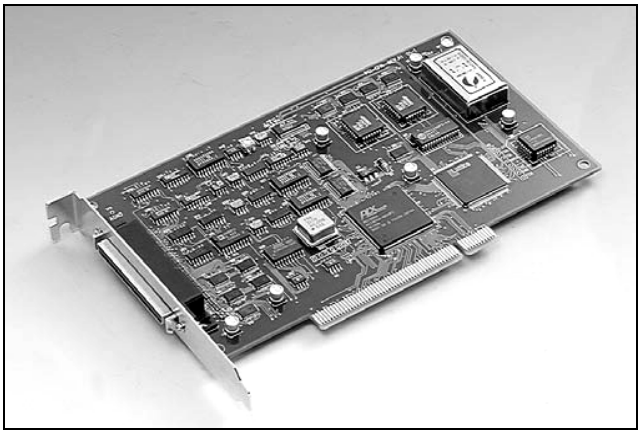

Figure 1. Advantech PCI-1716 multifunction DAQ card [1].

Table 1.Advantech PCI-1716 input ranges [1].

Mode	**Range [V]**				
Unipolar	N/A	0 ~ 10	0 ~ 5	0 ~ 2.5	0 ~ 1.25
Bipolar	±10	±5	±2.5	±1.25	±0.625

3. PROGRAM IMPLEMENTATION

Software application for audio signal frequency analysis was created in Microsoft Visual Studio 2005 as Win32 application with utilization of MFC library. Program can be divided to the three following logical parts that performs each specialized tasks:

- Data acquisition using Advantech PCI-1716 driver
- Fast Fourier Transform computation using FFTW library
- Data visualization and archiving layer

3.1. Data acquisition

Advantech provides software support for variety of programming environments and languages including Visual Basic, Delphi, Visual C/C++, Borland C and C++ Builder. For high speed conversions during which large amount of data are present can be very advantageously used functions utilizing DMA transfers for data acquisition. Due to low CPU utilization during data transfers from buffer to main memory there is enough free computing power for tasks related to FFT computation and data visualization. For example, Advantech PCI-1716 can in full speed (250 kHz sampling rate) provide approximately 490 KiB of sampled data per second.

Acquired audio data are stored in raw format to appropriate arrays corresponding to scanned channels from where they are processed by FFTW library. During the processing stage new data are acquired and transferred by driver using bus master DMA transfer. Due to this operation mode no data are lost even maximum sample rate is chosen.

3.2. Frequency analysis using FFTW library

FFTW is a C subroutine library for computing the discrete Fourier transforms by authors Matteo Frigo and Steven G. Johnson released under the GNU General Public License. Library supports both one-dimensional and multi-dimensional transforms with real or complex input data. Due to SSE/SSE2/3dNow! and Altivec support provides very high processing speed.
Usage of the FFTW library is very intuitive – can be split to these main steps:

- Memory allocation for input and output arrays (fftw_malloc)
- Create a plan containing all data needed for DFT computation (fftw_plan_dft_1d for one-dimensional DFT with real input data and complex output data)
- Start computation using created plan (fftw_execute)
- Process computed data
- Free the plan (fftw_destroy_plan)
- Free allocated memory (fftw_free)

FFTW use its own data type fftw_complex which is defined as array of two double type elements. Element with index 0 is real part and with index 1 imaginar part of complex number [2].

3.3. Program description

Main window of the developed application for spectral analysis of audio signal "Frequency analyzer" is depicted in the figure 2. Main dialog window integrates all necessary program components. In the left part are three systems of coordinates for data analysis visualization originating from three independent analog channels. In the right part if the window is list-box which informs about current program status and its settings. Below it are placed six buttons for program control and configuration. Using the "Settings" button can be set all important program parameters related to analysis and data archiving options. There can be set: number of samples for analysis (256, 512, 1024, 2048, 4096 and 8192 samples), window function (rectangular, triangular, Hamming, Hanning and Blackman), window overlapping (0 ~ 99 percents), sampled input signal archiving and analysis results archiving.

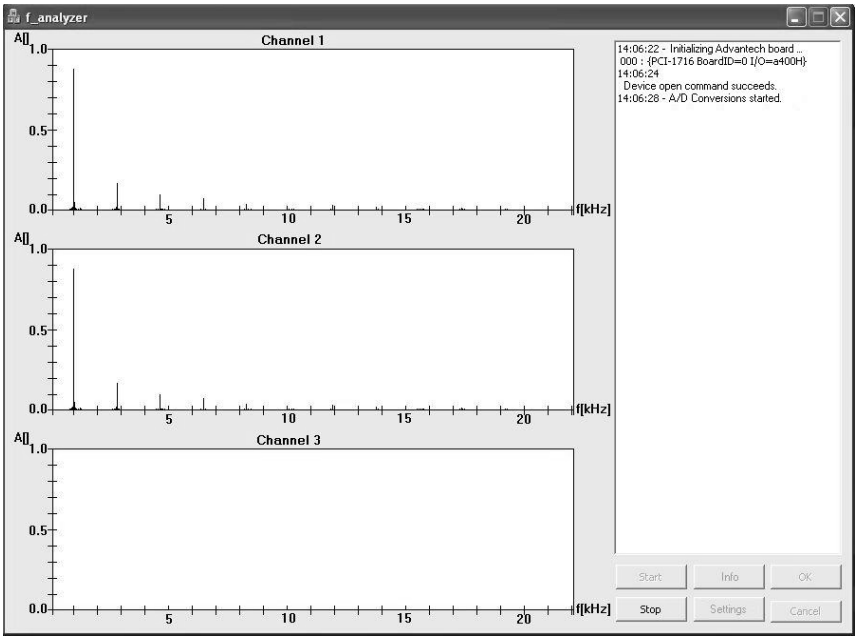

Figure 2. Main window of the Audio Analyzer application

4. PROGRAM VERIFICATION AND RESULTS

Program verification was performed on standard personal computer based on AMD Athlon 64 processor and Windows XP operating system. Testing audio signals were created in GoldWave application and played using on board integrated sound card with maximum available sample rate and resolution. Output of the sound card was connected with two input channels of Advantech PCI-1716 DAQ card. In the figure 3 are depicted program results when sine and square wave signals with frequency of 1 kHz were used. Results of ideal sine and square wave signal analysis are in figure 4.

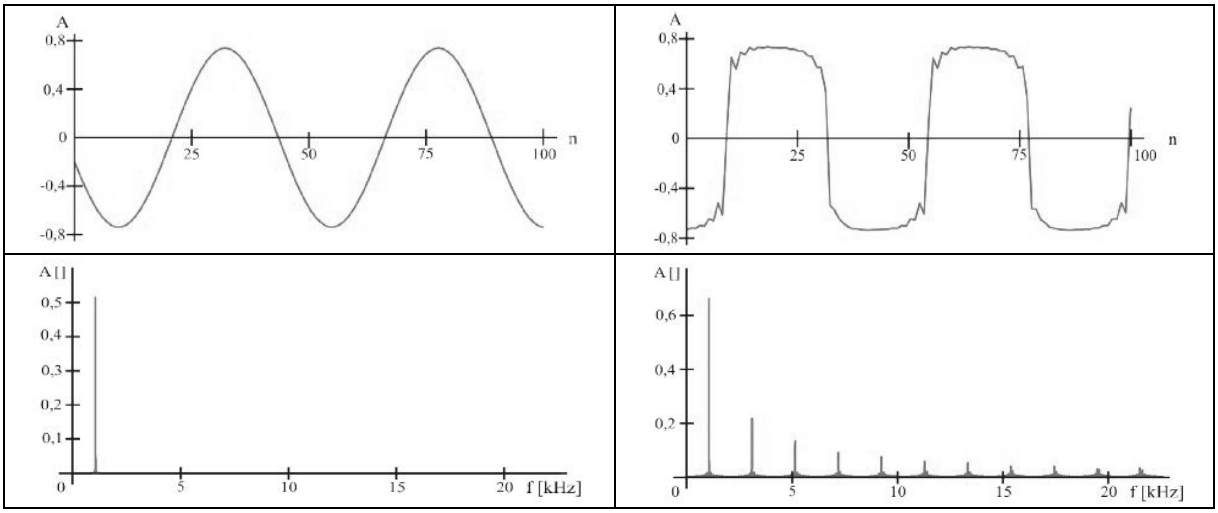

Figure 3. Acquired sine and square wave signal with f = 1000Hz, Hamming window

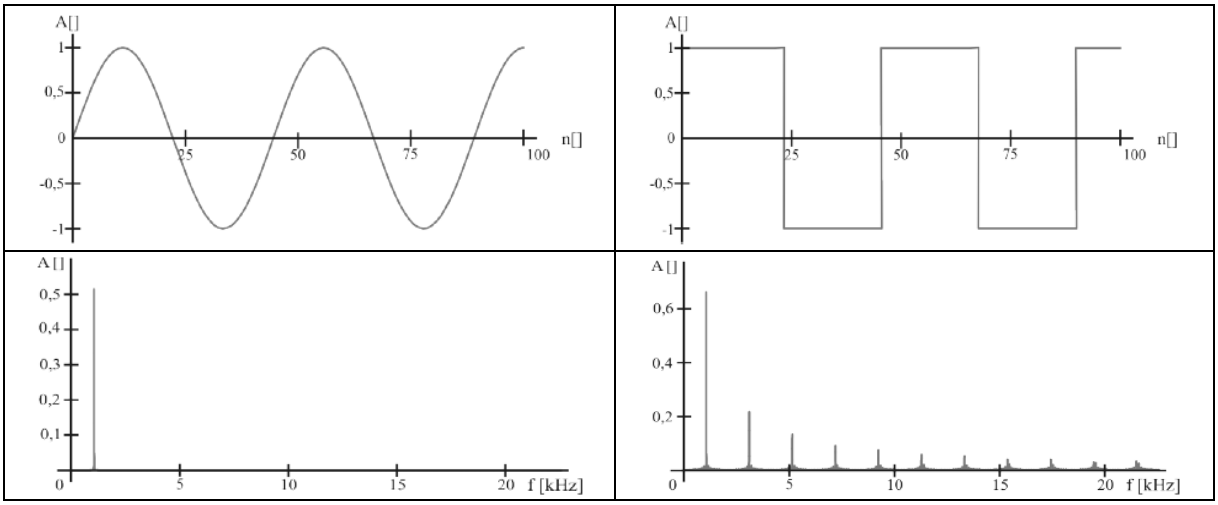

Figure 4. Ideal sine and square wave signal with f = 1000Hz, Hamming window

5. CONCLUSION

Paper deals with design of program environment for audio signal frequency analysis with utilization of standard personal computer equipped with Advantech PCI-1716 data acquisition card. Developed software environment was created in MS Visual Studio 2005 with utilization of FFTW library which is distributed under GPL license. It provides extended functionality such as window function selection (rectangular, triangular, Hamming, Hanning and Blackman) and window overlapping in range 0 ~ 99 percents. Analyzed signals can be visualized in graphical form in the main window of the program or saved to a file for further evaluation. Measured sound signals can be saved to the standard wav files in case of need.

6. ACKNOWLEDGMENT

The work was performed with financial support of research project 7088352102 MSM. This support is very gratefully acknowledged.

7. REFERENCES

[1] Advantech. PCI-1716 250kS/s, 16-bit High-Resolution Multifunction Card [online]. 2001 [cit. 2008-04-12]. Available from WWW: <http://www.advantech.com/products>.

[2] Frigo, M., Johnson, S. G. FFTW3, [online]. 2006 [cit. 2008-04-12]. Available from WWW: <http://www.fftw.org/#documentation>.

[3] SMITH, Steven W. The Scientist and Engineer's Guide to Digital Signal Processing. P.O. Box 502407, San Diego: California Technical Publishing, 1999. ISBN: 0-9660176-6-8.