AUTOMATED SYSTEM FOR DATA MEASURING AND ANALYSES FROM EMBEDDED SYSTEMS

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Abstract: - This paper presents the design of an automated system for signal processing in embedded systems. The design is worked out for an automatic predictive diagnostic system use. This automated system allows communication with embedded systems, an embedded systems control, a data collection from sensors, various signal analyses, and react to limits transcendence. Additionally, the developed system contains a transparent program environment for users control and monitoring. There is a possibility of setting various parameters, so this automated system is very universal and flexible. The paper shortly introduces diagnostic signal analysis methods, an applied embedded system with digital signal processor. Furthermore, there are specified other research targets with predictive diagnostic implementation and other system upgrades.

Key-Words: - embedded system, signal analysis, data measuring, predictive diagnostic system, digital signal processing.

1 Introduction

Today, signal processing and signal analyses in embedded systems are a much evolved and interesting research area. There are many methods and possibilities for utilizing this theoretical and practical knowledge. Signal processing applications and development are affected by modern computers and electronics.

A modern automated diagnostic and maintenance system is one of a sphere, where we can utilize new signal processing and computer possibilities. The modern automated diagnostic and maintenance system guarantees and increases stability and the economic efficiency of monitored devices. For diagnostic system development and improvement embedded systems can be used. The embedded systems enable very fast and safe system control. Personal computers PC can be utilized for data visualization and user interface.

The developing automated system for data measuring and analysis from the embedded systems enables many complex data manipulations. This system utilizes a modern comfort software environment on the personal PC computer. Basic system skills are communication with embedded systems, embedded systems control, data collection from sensors, various signal analyses, and reactions to limits transcendence. The whole developing automated system is very adaptable and user comfortable. There is no problem to use it for another signal processing and analysis system, not only for the automated diagnostic and maintenance system. Additionally, this system, to some extent, enables a connection and a data transfer with any embedded system using standard communication protocols.

2 Diagnostic and maintenance system

Automated diagnostic and maintenance systems are developed in the 1990's. This system manner is based on the data of the real states of monitored devices. So this allows the predicting of possible system events and problems. Today this manner of the diagnostic and maintenance control of the monitored devices is used, because this is the most effective, the safest and the fastest diagnostic system manner. The diagnostic system executes signal measuring, diagnostic methods and signal analysis for the detection of real states of monitored devices or for the detection impending danger failures or device damage. The automated diagnostic system is composed of sensors, which scan mainly device vibrations and device noises, rotation speed, movement values, device temperatures, fluid states and other areas. These measured data and signals are analyzed by a user or automatically. Monitored devices are controlled pursuant to analysis results of system states.

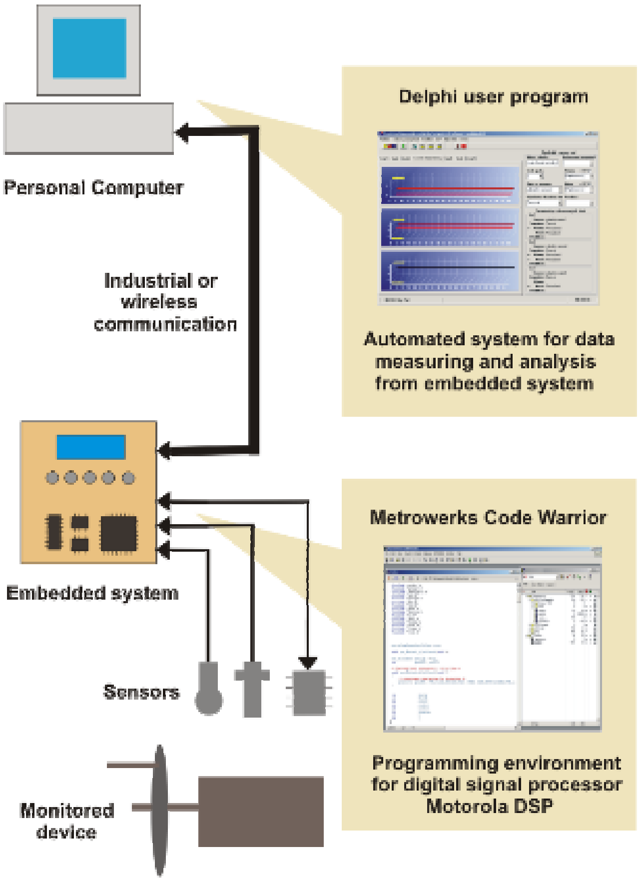

Fig.1. Diagnostic and maintenance system design

Our developing automated diagnostic system is composed of these basic hardware parts:

- **Sensors** – a data collection and no electrical signal transfer. Basic sensors are accelerometers for vibration measuring. The other sensors are for noise, rotation speed, movement value, temperature, and fluid state measuring.

- **Embedded system with DSP** – a signal processing and signal analyses. The main part of the developing automated diagnostic system is this control unit. It is the core for a system processing. Used processor, in this system, is a DSP digital signal processor.

- **Personal computer PC** – visualization and user interface. The developing automated system for data measuring and analyses is a very important part for the whole developing diagnostic system. Additionally, this system enables a universal set of embedded systems parameters. So it is applicable for various embedded systems and applications.

- **Connection** – a data transfer. There is very important safe and fast data movement. This developing automated diagnostic system should process in a very short time. Here can be used industrial or wireless buses and protocols for connecting embedded control systems and a personal computer. This connection enables real-time signal monitoring for users and user reaction to system operations.

3 Signal analysis methods

Measured signals are scanned from the monitored devices in the real-time. These values can be processed by various analysis methods to the applicable results. There are used statistical analyses and computations, too. The analyses methods enable the performance these basic functions in developing the diagnostic system:

- determine impending failures
- detect part of a device, where a failure can happen
- estimate the average time, when failure will be likeliest
- inform about real system states
- predict device states problems

The analyses methods usable for this developing automated diagnostic and maintenance system are:

- **Time signal analyses**
  This analyses type depends on the whole signal bandwidth in a time domain. The time signal analyses are much easer then frequency signal analyses. A results evaluation is almost based on specified critical values, which have not to be exceeded [6].

  Crest factor – the rate of effective signal value (PEAK) and maximum signal value (RMS) – PEAK/RMS. This analysis is sensitive to the mechanical failures already in the beginning.

  Kurtosis factor – a statistical signal analysis of normal Gaussian distribution and the value of acuteness observation.

  LIN – a signal analysis is based on a wide frequency bandwidth 0,8Hz-16kHz. This analysis is very simple and computedquickly.

  LF – a vibration speed signal analysis in a frequency bandwidth between 10 – 1000 Hz. This analysis is simple and fast computed too.

- **Frequency signal analyses**
  This analyses type is more precise. We can observe just a part of the signal bandwidth in a frequency domain. By this analysis, the fault can be located and it can be specified why it was happened, the phase and amplitude spectrum of the signal can be also traced, of course, if there is used a complex signal transform. In the case that some part of the signal is periodic, the fast Fourier transform (FFT) is used for converting the signal from the time to the frequency domain. Of course, these analysis methods are more sophisticated and the time consumption compares to the time analysis methods [6].

  Spectrum analysis – is the spectral composition of some signal and waveform. This method uses the fast Fourier transform (FFT), the mathematical processes transforming a waveform into compositions of frequencies in the spectrum.

  Cepstrum analysis - is the result of the Fourier transformation of the decibel spectrum. The Cepstrum is the Fourier transform of the logarithm of the Fourier transform FT. The complex cepstrum informs about magnitude and the phase of the initial spectrum, so it allows the reconstruction of the signal.

  Octave analysis – the signal spectrum is worked out and converted in a special interval. This interval is defined between one musical note and another with half or double the frequency. So the next value in the interval is double the actual frequency, and previously is half the frequency.

  Envelope analysis – Complex method enables a very detailed detection and analysis. A diagnostic method is designated for a sophisticated solution, when is possible to dedicate part, type of failure, state failure. There is used the theory of signal modulation and demodulation.

4 Embedded system with DSP

An embedded system is special purpose computer system, which is encapsulated and housed on a single microprocessor board. This system performs pre-defined tasks and it has specific requirements. It is of a contrary character to personal computers. The embedded systems often obtain a small memory, a slower processor and needed interfaces. It guarantees lower cost and smaller power consumption. Programs often have to run with real-time and application-specific integrated circuit limits. Designers use assemblers, compilers, debuggers to develop the embedded system [1].

In developing a project, the embedded system contains a DSP digital signal processor for process and signal computation. This new improvement of the diagnostic system design is very powerful and it could control devices better and faster than the old ones. Thanks to this embedded system, we can automatically monitor values, execute, analyze, monitor the equipment state, and react to system operation. For modern applications, it is necessary to process complex computations in a very short time (RT - real time). So for processing, the digital signal processor DSP is mostly suitable [3].
DSP is a Harvard architecture processor with special features. The architecture enables using a more system buses for the data and instruction transfer inside processor [4]. DSP is RISC (Reduce Instruction Set Computer) processor type. One of DSP special features is Pipe-lining. It means, they process more instructions in the one instruction cycle. It enables using special MAC instructions for filtering. There is executed: the reading, sum, storage function in one instruction cycle.

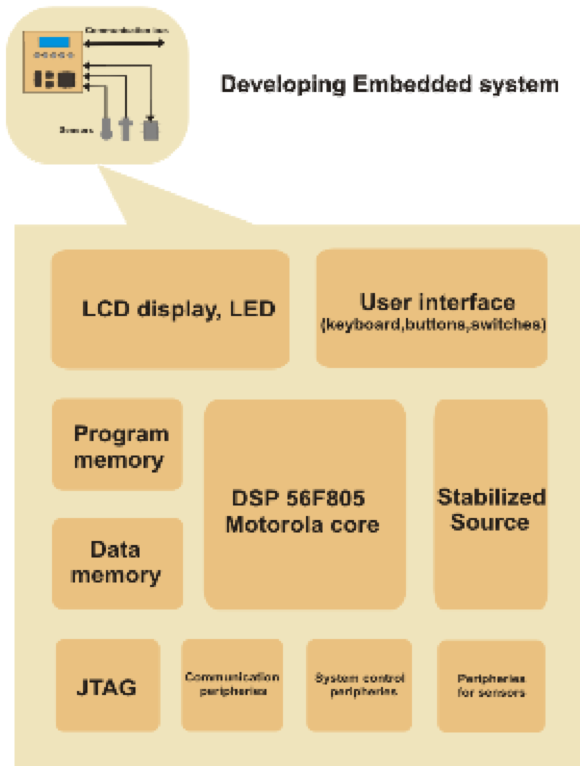

Fig.2. Function blocks of developing embedded system

For this project, we have been working with the digital signal processor MOTOROLA DSP 56F805. Maximum core frequency is 80MHz, and 8MHz crystal. The program memory is internal FSRAM 64K x 16 bits and 64K x 16 bits is a data memory. It is 16 bit processor with a sufficient performance and a number of peripheries. For programming, there is the development software - Code Warrior - transparent and comfort programming in C and Assembler languages.

5 Automated system design

The developing automated system is basically used for visualization, state monitoring, data transfer, the user interface, and connected embedded system control. This system is created in the programming environment Delphi 7. The program runs on the personal computer. This comfortable user environment of the developing system is designed for various embedded control systems. It enables selectable system parameter possibilities.

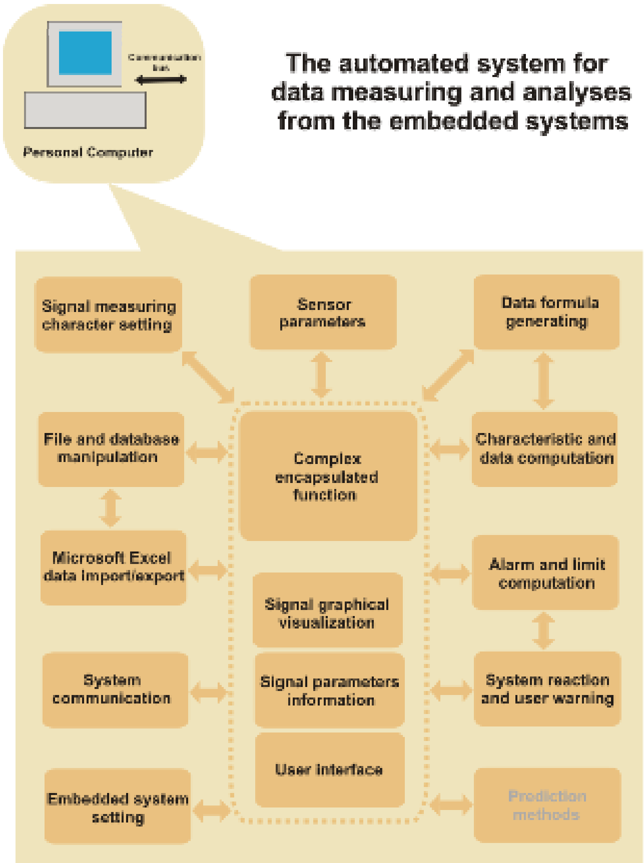

Fig.3. Function blocks of automated systems design

The developing automated system is created like a operating user program. This program is customized for comfortable user control and it is very well suited for data measuring and the analysis from embedded systems. The programs basic screen is composed of these easy common user components:

- **user menu** – is placed on the top of the program screen. There are selectable parameters of data measuring and analysis obtained from the embedded system. The selectable parameters appertain to peripheries, communication protocols, data sequences, sensors, limits and alarms, system reactions, signal analyses, computations, prediction, and files. Furthermore, there are program help and the finish item.

- **rapid icons** – are often used, and important data parameters settings. There are placed under the user menu. These icons make easier and faster user control.

- **graphical sheets** – are several sheets with one, two or three graphs. Inside of graphs are measured or computed data, which are sent from the embedded control system. They are placed in the middle of the program screen.

- **graphical setting items** – are for user data graph definitions. These items are placed on the right side of the program screen. The program user can define the name of the graph sheet, the number of the graph, data from the sensor, data computation, characteristic and analysis, the alarms and limits, the defined interconnection. So, all these user settings are determined for the displayed graph.

- **parameters of displayed data** – are placed under the graphical setting items. Information about just active graphical sheet is displayed. The information is about the graphs of the active sheet. There is information about the sensors, the data computations, the data characters, the alarms, the limits and prediction methods.

The sensor setting is one of the automated system possibilities. There is a special window, which is displayed in the basic program screen. In this window, a user defines a sensor name, scan frequency, sensor bandwidth, sensor character, sensor notation. Other parameters could be added, when they will be needed.

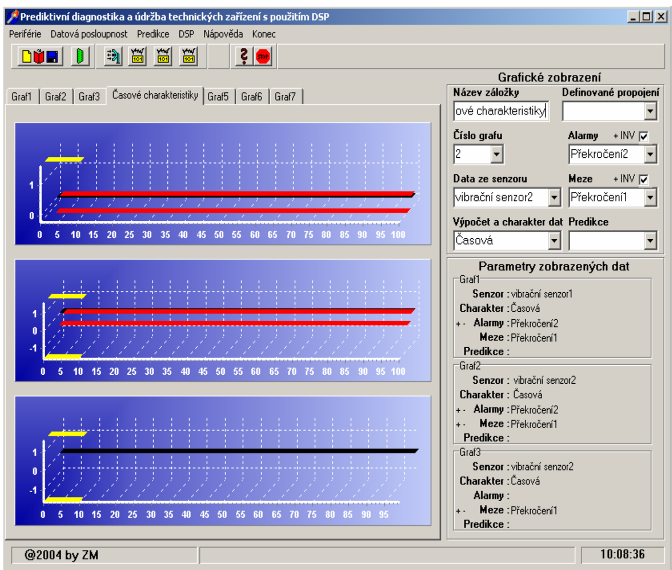

Fig.4. Basic screen of the automated systems program

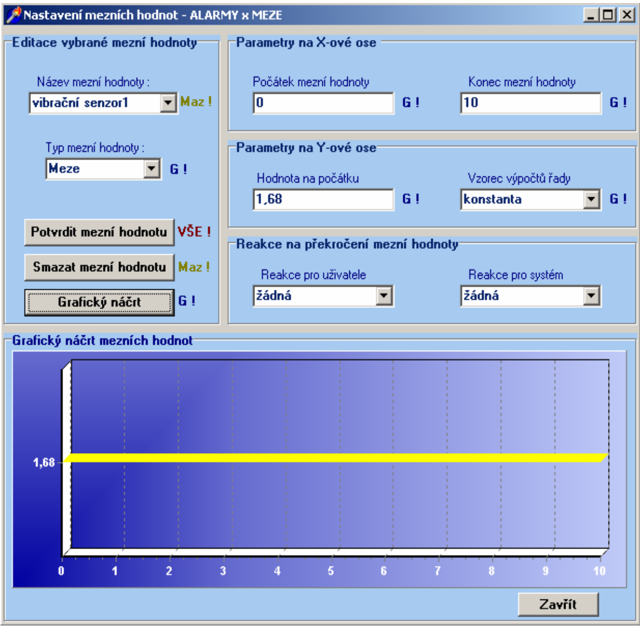

Fig.5. Program window for the limit values setting

Another setting window of the automated system is the alarms and limits setting. This special window is presented in Figure 5. The limit value name is adjustable, as well as the type of limit value, the limit value start, finish, the initial value, the formula of limit series. Furthermore, there is the possibility of setting reactions. The reactions can be determined for the embedded system or for the user visualization. There is the possibility of setting three reactions for each type. The user can display an adjusted limit or alarm in a graphical sketch, which is placed under the setting area in this window.

The next special window is designated for computation and characteristic settings. This window is similarly placed in an automated system like the previous setting windows. The setting functions are partitioned into:

- **characteristic and data computation setting** – enabling various data computations and the signal analyses. These settings and data series computations can be saved or displayed.

- **alarm and limit computation setting** – defines series calculation of the alarm and limit settings.

- **setting of reactions** – defines user visualization warning and embedded system reactions, which are ordered by this automated system.

- **computation setting and formula generating** – allows easy computational declarations or analysis parameters definition.

The communication with embedded systems has to be fast enough and very safe. For real-time data computation communication is a very important and indispensable problem. This developing automated system is customized for serial RS232 and CAN industrial communication. The communication choice is executable by the peripheries menu item. The PC contains a CAN communication interface card PCL841 for the data transfer from the embedded system. Later, of course, the system upgrade and the communication bus improvement is possible. The special window for the communication protocol setting is placed as the previous special program windows. There is a communication protocol setting at a higher part of the window. A user can set each byte in a decimal or binary form number, and its name. There is a communication data packet setting at the lower part of the window. A user sets the name of the packet and its individual byte names. These setting functions enable various configurations of the communication with any embedded systems.

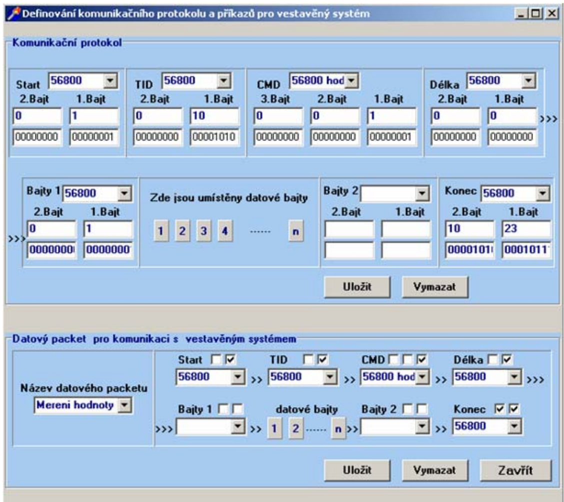

Fig.6. Program window for the communication setting

One of the very important functions of whole developing automated system is data saving and data downloading from the defined databases. The user window for files manipulation is partitioned to:

- **current file** – allowing the setting of the current file.

- **current directory** – is composed for the drive choice and for the current directory setting.

- **configuration file** – is for the chosen current configuration file name from the setting and for the configuration sphere, which is declared.

- **data file** – is for the chosen current data file.

- **data and configuration files for Excel** – works and transfers the data to Microsoft Excel.

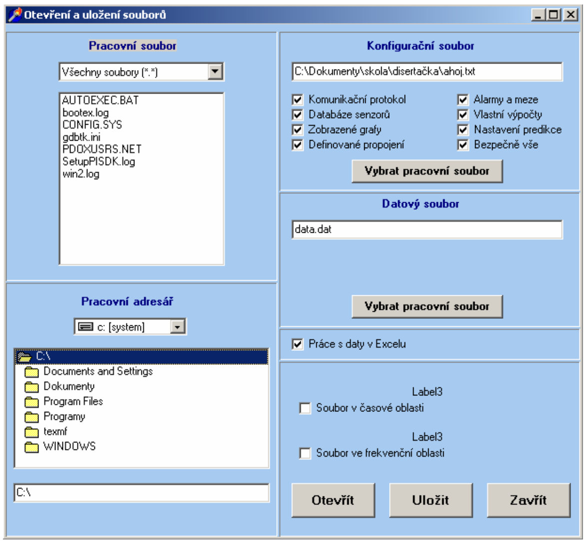

Fig.7. Program window for the files manipulation

The last function of the automated system is no less important, because it interconnects all other predefined functions to the one united encapsulated complex. This complex defines - how, what, when - measure, communicate, react, save, open, monitor, display, control all together. This function setting is sophisticated and a difficult user problem.

6 Research targets and system upgrades

This developing automated diagnostic and maintenance system is possible to extend and improve. We suppose that, after the whole project checkout, we will implement the next more sophisticated improvements. For example, we will implement more communication protocols, more analysis methods, and other parts.

One of the major research targets is a system upgrading more accurate and faster diagnostics and maintenance computations. The solution of this problem could be predictive or improved control methods implementation. This is a very interesting and formidable task. It is necessary to use a complex mathematical theory and joint it with digital signal processing. For this, we will use a mathematical programming environment – Matlab Simulink and helpful Matlab toolboxes. This program runs on a personal computer. The signal processing toolbox is very helpful for Fast Fourier transformation, various filters, correlation, statistical and other signal computations [2]. By simulation in Matlab Simulink, we can verify measured and calculated real diagnostic system data with simulating data. By these computations, we could recognize the best methodology for the control and the diagnostic of a monitored device. Additionally, we can transfer these pieces of knowledge to the developing embedded system, to the developing program for the diagnostic and maintenance system.

7 Conclusion

This paper describes recent developments and future possible research in embedded system utilization. The purpose of this project is to improve and to adapt methodology of computations and diagnostic analyses for embedded systems. The project is specialized on automated predictive diagnostic and maintenance systems. The presented application is one of the basic parts of the whole automated diagnostic system and it runs on a personal computer. This part represented the user program environment and the user system interface. The developing automated system for data measuring and signal analyses is applicable for various applications with the embedded systems. This variable character of the system is enabled adjusting the program parameters. The automated system enables the setting of the communication protocol, the sensors, the measuring, the graphical output, the signal analyses, the data computation, the alarm and limits, the embedded system reaction, the embedded system control, and file and database manipulation. The automated diagnostic and maintenance system application has been developed for real-time and short time data measurement, communication, analysis, and reaction with the use of an embedded system.

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