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Ultrasonic tomography for reflection and transmission wave analysis

***Abstract**. The main purpose of this work is to present a solution based on ultrasound reflection and transmission tomography. The reflective ultrasound tomograph is designed in a modular way. The first module consists of a motherboard connected to an analog signal conditioning board and a liquid crystal display with an integrated graphics processor. The second module consists of a high voltage pulser with a 64 channel multiplexer. The presented control methods include issues related to the processing of data obtained from various sensors located in nodes. Monitoring takes place as part of data processing and the parameters obtained and processed. The device has been designed for tomographic measurements of the properties of various technological processes..*

***Streszczenie.** Głównym celem tej pracy jest przedstawienie rozwiązania opartego na ultrasonograficznej tomografii refleksyjnej i transmisyjnej. Tmograf ultradźwiękowy zaprojektowano w sposób modułowy. Pierwszy moduł składa się z płyty głównej połączonej z płytką kondycjonowania sygnału analogowego oraz wyświetlaczem ciekłokrystalicznym ze zintegrowanym procesorem graficznym. Drugi moduł składa się z impulsatora wysokiego napięcia wraz z 64 kanałowym multipleksерem. Prezentowane metody sterowania obejmują zagadnienia związane z przetwarzaniem danych uzyskanych z różnych czujników znajdujących się w węzłach. Monitorowanie odbywa się w ramach przetwarzania danych oraz uzyskiwanych i przetwarzanych parametrów. Urządzenie zostało zaprojektowane do tomograficznych pomiarów właściwości różnych procesów technologicznych.. (**Tomografia ultradźwiękowa do analizy fali refleksyjnej i transmisyjnej**).*

Keywords: ultrasound tomography, sensors, multiplexer.
Słowa kluczowe: tomografia ultradźwiękowa, sensory, multiplekser.

Introduction

Ultrasound tomography enables the analysis of processes occurring in the object, analysis and detection of obstacles, defects and various anomalies. The designed measuring system is an innovative solution, especially effective in data analysis [1]. Knowledge of the features of each tomographic technique solution, the application allows you to choose the appropriate method of image reconstruction [3-21]. Various methods can be used to solve the optimization process [22-36]. The main purpose of the work was to present the designed measuring system for tomographic measurements of the properties of processes occurring in tanks.

Ultrasonic reflection tomograph

When designing a device based on ultrasound reflective tomography, the following design assumptions were made (Fig. 1):

- generating bipolar high voltage pulses forcing a piezoelectric transducer (about 142 V p-p),
- analog signal capture using a fast ADC converter,
- software control of analog signal gain,
- adjustment of the number of stimulus pulses,
- forced frequency regulation,
- analog processing of the analog signal to the envelope,
- user interface made on a 5-inch LCD touch screen,
- multiplexing of induction signals and signals generated by 32 piezoelectric transducers,
- communication with a computer via USB 2.0 High Speed,
- switches 8-channel piezoelectric converters in the M12 standard.

The reflective ultrasound tomograph has been designed in a modular way. The first module consists of a motherboard connected to an analog signal conditioning board and a liquid crystal display with an integrated FT811CB graphics processor. The second module consists of a high voltage pulse generator with a 64-channel multiplexer. The digital module buses have been connected to each other using an RJ45 cat. Cables 6a.

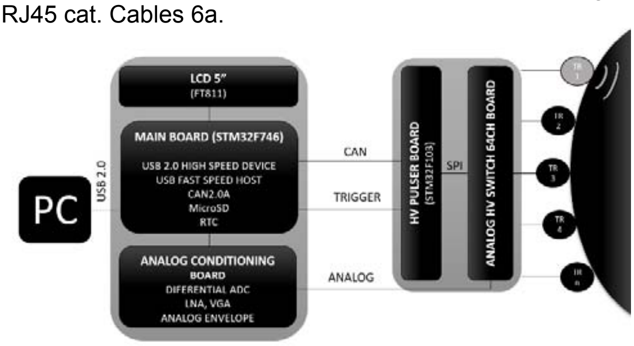

Fig. 1. Block diagram of a reflective ultrasound tomograph.

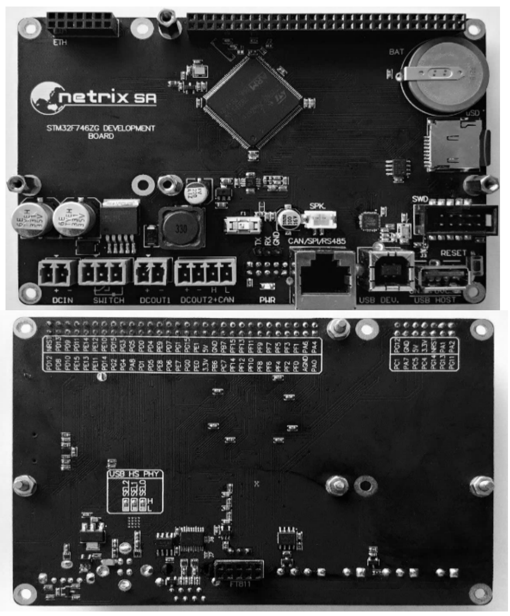

Fig. 2. Photographs of the complex PCB of the module with the STM32F746ZG microcontroller.

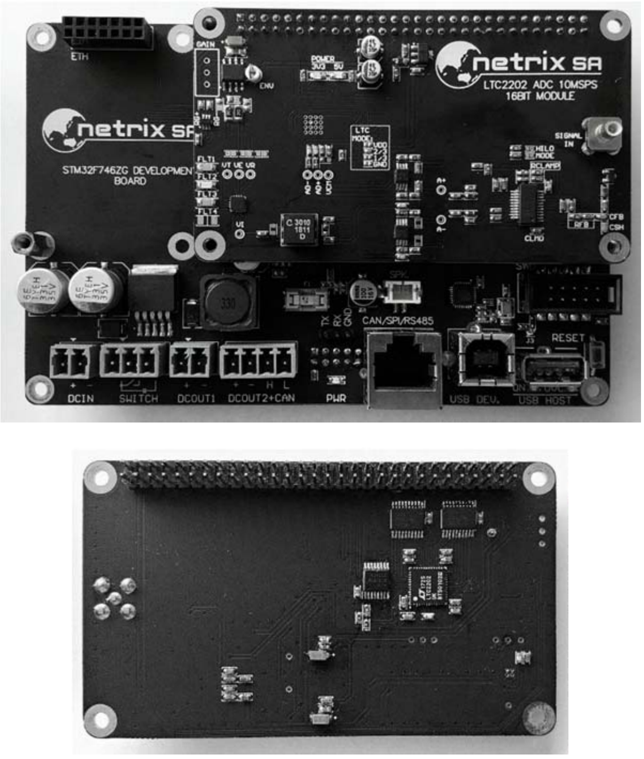

Fig. 3. Photographs of the assembled and mounted analog module board.

The analog signal was obtained in the SMB standard. To limit the number of wires entering the multiplexer from ultrasonic transducers, M12 connectors were used, one for every 8 channels. Communication with the computer was carried out in the USB HS 2.0 standard, in addition it was possible to connect external storage media, such as a micro SD card and portable USB drives. The modular design allows easier and faster testing of key system components. In addition, it creates the possibility of using ready-made modules in future projects, and also reduces the risk of damage to the entire device to its specified range.

Fig. 4. Photograph of the FT811CB display.

When designing the main module of the device, great emphasis was placed on its universality. The size of the printed circuit board depends on the dimensions of the FT811CB display. The main module board itself will be mounted under the display. The board allows you to connect external storage media: micro SD cards, portable drives to the USB Fast Speed port. The board has a spare RTC battery, spare registers, EEPROM memory. Communication with the computer can be implemented in the USB High Speed 2.0 standard. The debugger connector and serial port are connected. CAN, SPI, RS485 buses are output via the standard Cat 6a connector. Other I / O ports come from popular terminal blocks.

Fig. 5. Tomograph mounting concept in a pele case - side view.

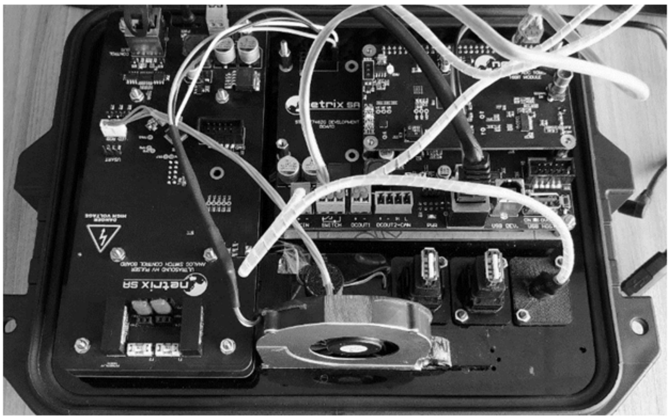

Fig. 6. Photograph of the inside of the tomograph.

Fig. 7. Photograph of the tomograph front.

The analog module is an improved integrated version of the previously presented solutions. The main amplification path was made using the AD8331 measuring amplifier. Gain adjustment at this stage is done by changing the voltage at the GAIN input using a DAC converter built into the STM32F746 circuit. The amplified differential signal is then fed to two separate measuring paths. One of them is the fast LTC2202 10MSps analog-to-digital converter with 16-bit parallel output, while on the second measurement path the signal is converted into envelopes using the ADL5511 circuit and additionally amplified by the AD623 measuring amplifier. This track was strengthened using the MCP4017T adjustable digital potentiometer. The signal processing circuit requires appropriate selection of the value of FTL1-4 filtering capacitors. In the final stage, the signal prepared in this way is sampled by three analog-to-digital converters built into the STM32F746 microcontroller, operating in triple interlace mode. This allows a 3-fold increase in signal sampling rate. As a result, it gives the possibility of sampling with a frequency of up to 7.2MSps (3x2.4). However, setting the maximum ADC clock speed in the microcontroller would require a reduction in the clock speed of the entire processor, and therefore the maximum clock speed that was achieved for this application (envelope measurement) was 5.1MSps (3x1.7). The timing of both transducers was performed using an internal hardware counter. This solution allows for accurate adjustment of signal sampling

The FT811CB display has a 5 "screen diagonal, 800x480 resolution and a capacitive touch layer with multitouch support. The built-in FTDI controller of the display distinguishes the video engine (EVE2 - Embedded Video Engine). Allowing effective control of the display only using the SPI bus involving a small percentage of the microcontroller computing power. The FT811CB display has a 5 "screen diagonal, 800x480 resolution and a capacitive touch layer with multitouch support. The built-in FTDI controller of the display distinguishes the video engine (EVE2 - Embedded Video Engine). Allowing effective control of the display only using the SPI bus involving a small percentage of the microcontroller computing power.

Conducted tests

Module tests were carried out for an ultrasonic transducer with a 2.4MHz resonant frequency in a plastic vessel with a diameter of 34 cm with full immersion sensor in water.

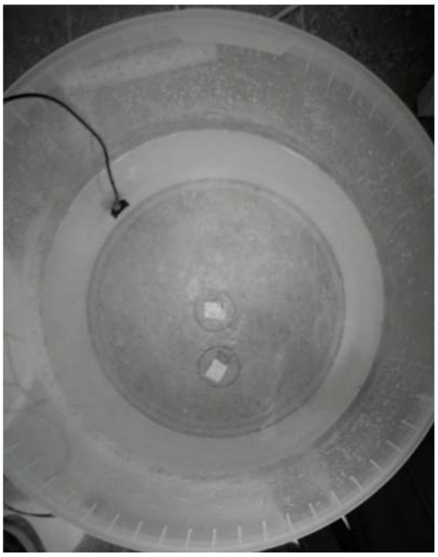

Fig. 8. View of a vessel with a submerged sensor in water.

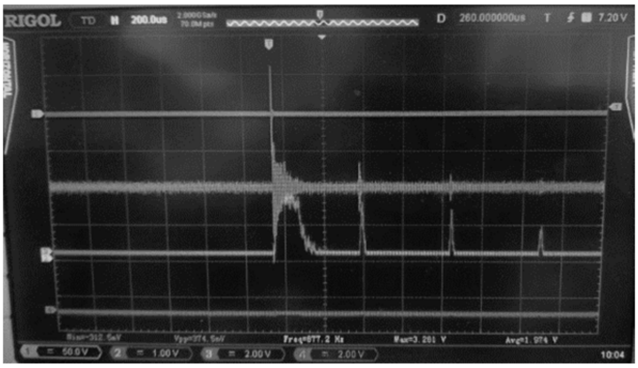

Fig. 9. Oscillograms for a dish without a phantom from Figure 8.

Figure 9 shows the course of the excitation signal of the ultrasonic transducer (> 100Vp-p), the received analog signal, and the signal envelope. On oscillograms one can observe the effect of multiple reflections of the signal from the vessel wall and long-lasting vibration of the transducer just after extortion.

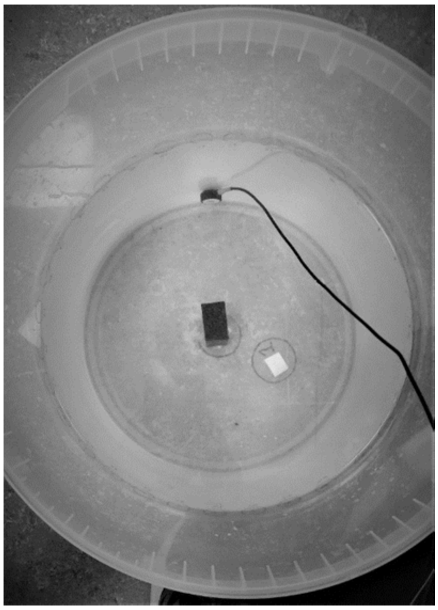

Fig. 10. View of the vessel with the sensor immersed in water and the steel phantom.

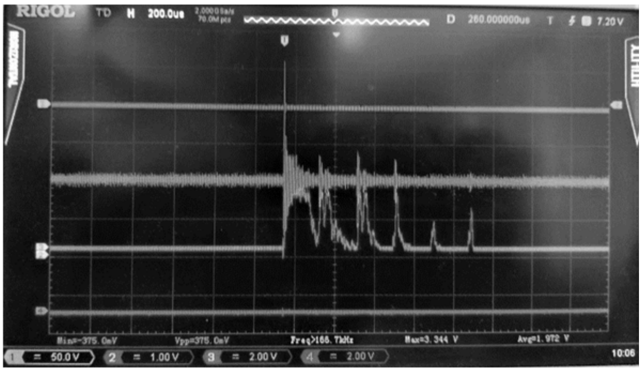

Fig. 11. Oscillograms for the phantom vessel from Figure 10.

Figure 11 shows the waveforms after inserting a steel bar into the vessel. The oscillograms show characteristic double-top jumps of the amplitude after the signal is reflected from the first and second wall of the bar. Similarly to the oscillograms from Figure 9, one can observe the effect of the "infinity mirror" or multiple reflections

Conclusion

The article presents a solution based on ultrasonic tomography. An original tomograph for measuring and processing data obtained from various sensors was designed. Monitoring takes place as part of data processing and the parameters obtained and processed. The device has been designed for tomographic measurements of the properties of various technological processes. The device is designed in a modular way, it consists of a motherboard connected with an analog signal conditioning board and a liquid crystal display with an integrated graphics processor, a high voltage pulser with a 64 channel multiplexer. The device was designed for tomographic measurements of the properties of various objects.

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