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INTELLIGENT ULTRASONIC SENSOR

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Summary: *In the present paper the design and the realization of intelligent ultrasonic sensor, destined for non-contact invesigation of materials, have been described. A scheme solution of this device is presented as well as during its development some basic opportunities for operation are prognosticated with the purpose larger universality*

Keywords: *Ultrasonic, Ultrasonic sensors, Non-contact method, Intelligent system*

1. INTRODUCTION

The optimal running of technological processes in the industry is determined to a not inconsiderable extent by the correct measurement of their parameters.
The reliable and exact mesurement of process characteristics is of significance for investigations and optimal control of technological processes as well for safety service of equipments and aggregates. In the practice transmitters from new generation have already been imposed, so called smart and intelligent models. They support calculating possibilities and functions, which expand and improve the obtained information depending on the specificity of different applications. The target of consideration in this paper is constructive and metrological characteristics of intelligent ultrasonic sensor module, destined for non-contact investigation of objects and material media.
The development is a part of mobile unit for non-contact ultrasonic investigation of materials.
The basic stages in this development are as follows:

- Synthesizing of a principal scheme of intelligent sensor for non-contact ultrasonic investigation of materials;
- Realizing of an intelligent sensor for non-contact ultrasonic investigation of materials;
- Developing of an algorithm for operation and software of the intelligent sensor;
- Designing of a controller for analyzing and classifying the signals received by intelligent ultrasonic sensor;
- Designing and developing of algorithms about spectral analysis which are suitable for embedding in the mobile device;
- Analyzing of the results from made measurements with different ultrasonic sensors, etc.

2. CONSTRUCTION OF INTELLIGENT ULTRASONIC SENSOR

Functionally and constructively, the intelligent ultrasonic sensor (IUS) consists of three basic modules (Figure 1) sensor module, where piezoceramic sensitive elements are found, microprocessor (computing) module for measurement and interface module for communication according to the corresponding protocol with control system, controller, PC and portable communicator. In Figure 1 the functional scheme of IUS is shown.

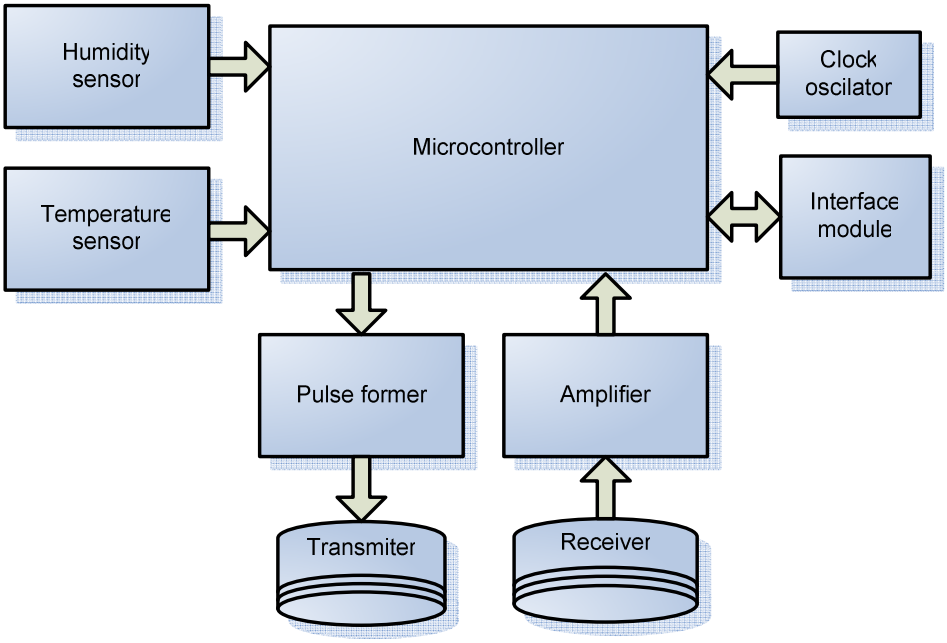

Figure 1: Functional scheme of IUS

3. SENSITIVE ELEMENTS OF SENSOR MODULE

The basic requirements towards sensitive elements are high sensitivity, prolonged stability of operation, repetition of results and small temperature dependence. In the role of sensitive element, ultrasonic piezoceramic sensors from a type of UST40T and UST40R or 125SR250B are used. The sensors UST40T and UST40R function at 40 kHz, but 125SR250B - at 125 kHz. The signal for excitation of ultrasonic emitter is a package from rectagular impulses with its resonant frequency. According to the recommendation of firm-manufacturer of ultrasonic emitters, about the full hesitation of piezoelements, it is necessary a package from exciting impulses with indicated parameters to be fed (Figure 2).

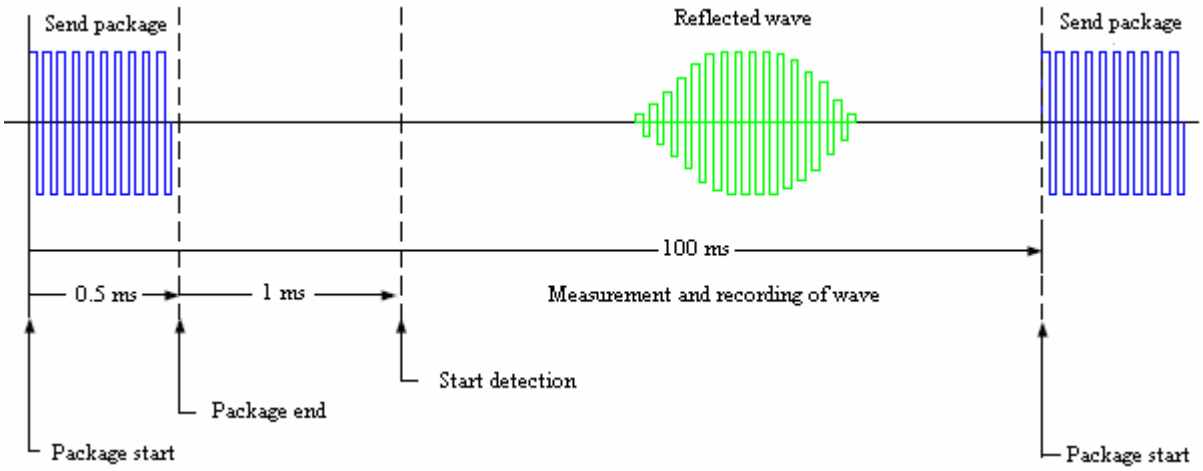

Figure 2: Scheme showing the operation principle of blocks: receiver and transmitter

The transmitter in sensor emits an acoustic wave in the form of impulses with frequency 40 or 125 kHz, which reach to the object, reflect and return back up to the receiver. The reflected wave is accepted by acoustic

transducer and is amplified by measurable amplifier. The output of sensor is analogue and it is fed to the microprocessor about transformation in digital type. The output of amplifier is led to plug and socket as well as it can be measured by external devices, but the signal level is a non-linear function of the type, the density and the thickness of object. For proper action of sensors, the reflecting surface of object must be perpendicular towards the emission direction. The basic advantage of sensor is comparatively large distance about measurement, the independence on optical properties of object and the linear connection between the output signal and the object space. From disadvantages can be mentioned the necessity for suitable surface of object and its arrangement toward the sensor, comparatively large time of reaction (100 ms), the availability of minimal object space as well the dependence of indications on the air state (temperature, humidity, pressure). The influence of environment temperature on the indications of ultrasonic sensors is compensated by embedded automatic temperature compensation operating in the range from -40 up to +100°.
For measuring the temperature and the humidity, sensor from a type of HIH-4602c of HONEYWELL firm is used. The sensor consists of integrated sensitive elements in one casing about measurement of temperature and humidity. The output analogue voltage signal is proportional to the humidity, but the resistance – to the temperature. The signals are fed directly towards the microcontroller. The power supply of sensor is unipolar DC 5V. The range of measured humidity is from 0 up to 100%. On the basis of measured values about temperature and humidity in the microcontroller, correction of measured signal by the ultrasonic sensor is made. It must not be forgotten, that the heated objects change the configuration of reflected wave, which leads to an error at measurement of the distance and the object state. By means of inclusion of microcontroller in the processing module, additional improvements at the measurement accuracy are realized. The typical values of linearity are below 1%, the repetition is some tenth parts from the percent, but the reaction time is around 0,1 s.

4. COMMUNICATION OPPORTUNITIES

The developed IUS is worked out in three varieties regarding the communication interface (USB, Ethernet and RS485).
At RS485 the connection with the interface of control system is based on a two-conducted line as each IUS is connected in parallel and is addressed individually. On one bus it can be connected up to several units in branchy structure. About fast or critical processes, included in loops for controlling, peer-to-peer communication with the interface of control system or PLC is recommended. For realizing of USB or Ethernet communication, IUS is fed along the corresponding interface cables.

5. FUNCTIONALITY OF MICROPROCESSOR MODULE

In Figure 3 the block diagram of an algorithm for module control is shown.
In Initialise block, the primary initialization of module is performed. The values of process variables are taken by the EEPROM-th of microcontroller. These parameters can be changed at any time after supplying a command through the interface USB module. The acceptance of commands is fulfilled according to interruption, but their processing become in Parser block. The measurement process begins after supplying a command from the master unit. IUS responds with a command about readiness for measurement. Then, the measurement process starts. The measurement process includes the following stages:

- Measurement of humidity (HumidityMeasurement module);
- Measurement of temperature (TemperatureMeasurement module);
- Measurement of distance up to the object and determination of the time for record origin (DistanceMeasurement module);
- Sending a sequence of impulses with operating frequency 40/125 kHz (SentPulse module);
- Starting of measurement on a definite period Δt and recording of measured data in a buffer (Value[i] = GetADC() module). The duration of measurement is determined by the type of substance, its phase and it varies in the range from 2 up to 10 ms;
- Rectification of measured values (Rectification module);
- Sending of measured data on master unit (SentValues() module).

It is prognosticated 1ms time for preventing the error from acceptance of emitted signal by the transmitter before its return from the reflected surface.
Two basic operation modes of IUS exist. The first way is Periodic Sampling, which is made through a definite interval of time set preliminarily along the interface channel. The intervals can be within too wide boundaries and even be changed in the process of operation. The second way is Single Sampling, which is made according to a request from the guiding controller.

At a definite interval of time the microprocessor also fulfills self-diagnostic functions, keeps up with the state of sensors and output signal as well as at availability of errors through the interface it generates a message for failure or other status.

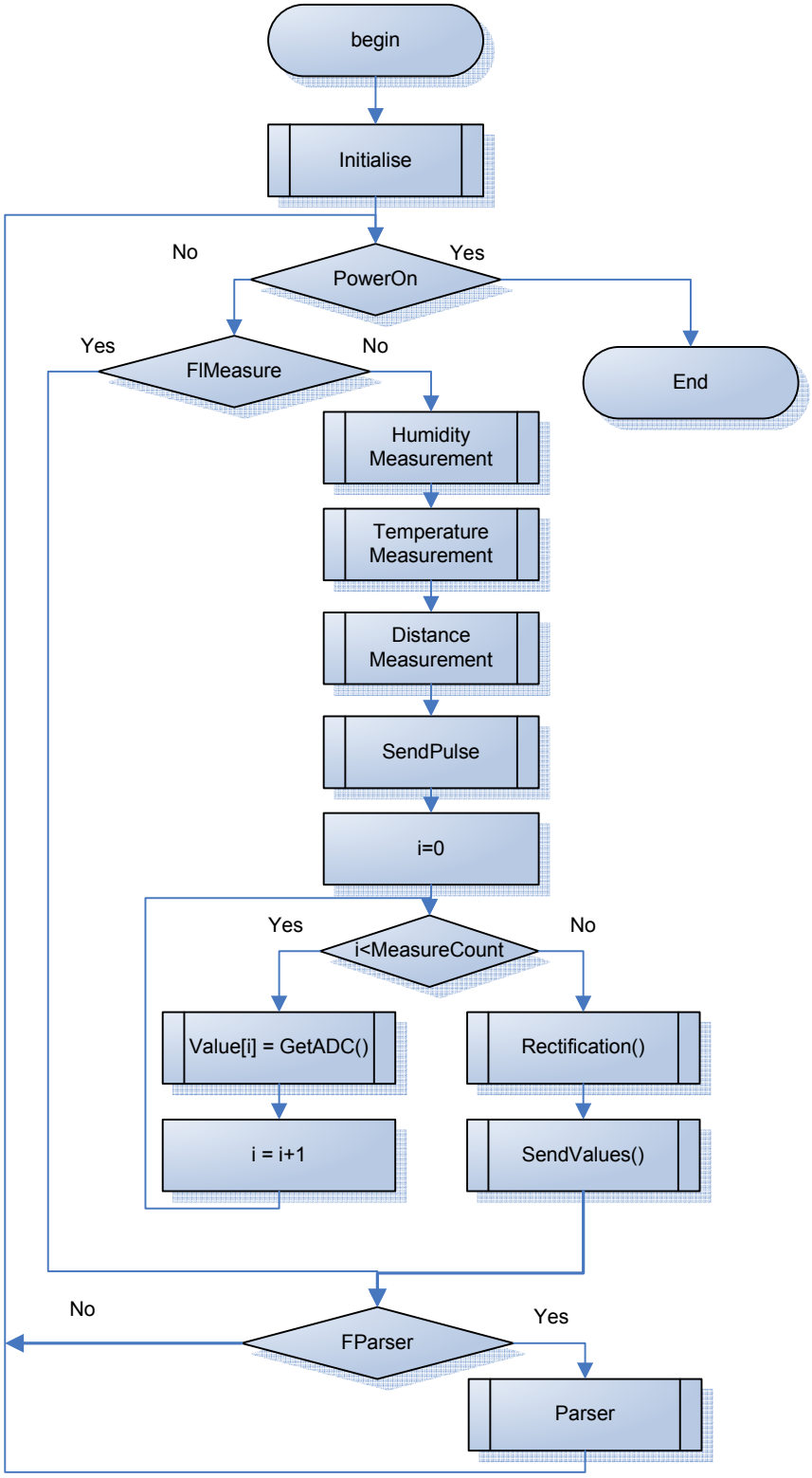

Figure 3: Algorithm of operation about receiver-transmitter module

6. CONCLUSION

The developed intelligent ultrasonic sensor affords an opportunity for performing of non-contact non-destructive analysis of materials. It is a part of mobile device with a possibility for embedding in automated manufacturing systems, at which it is required fast and exact determination of the type and the state of substances, compositions of mixtures, material mediums and their production phases. Testing measurements of liquid and solid substances have been made as well as one part of them is shown in Figure 4 and they prove the serviceability of this development.

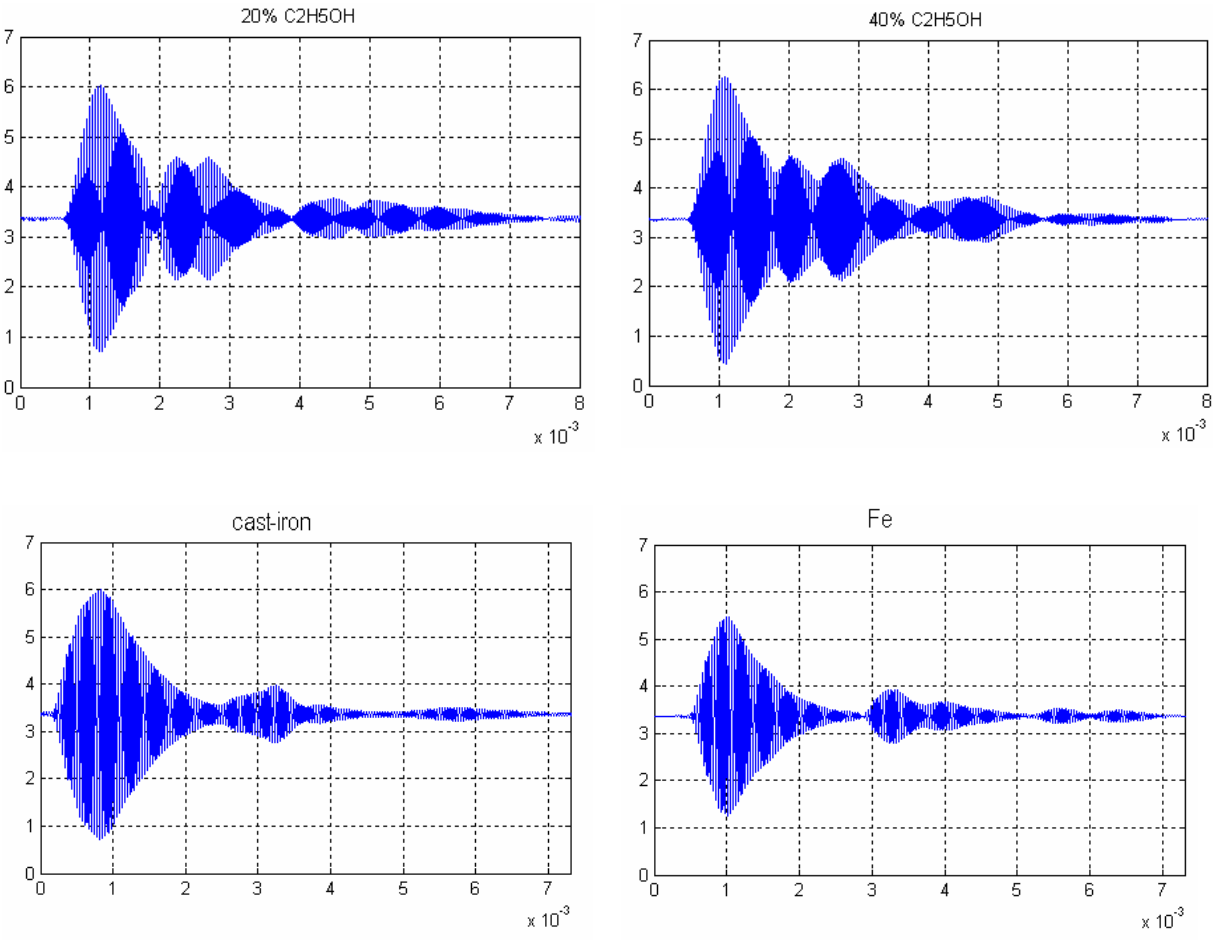

Figure 4: Experimental data from measurements made by meas of IUS

REFERENCES

[1] Baltes, H., W. Göpel, J. Hesse: Sensors Update. Volume 3. Sensor Technology-Applications-Markets. Weinheim-Berlin-New York-Chichester- Brisbane-Singapore-Toronto, Wiley-VCH Verlag GmbH, 1998.

[2] GM Electronic spol. s r.o. 1990-2008, UST40T, http://www.gme.cz/cz/index.php?page=product&detail=641-019, 2008.

[3] PIC32MX5XX/6XX/7XX Family Data Sheet High-Performance, USB, CAN and Ethernet 32-bit Flash Microcontrollers, Microchip Technology Inc, 2010

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