DESIGN OF ULTRASONIC SENSOR WITH HIGH RESOLUTION FOR INDUSTRIAL SYSTEM CONTROL

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Abstract: In recent years the acoustical engineering researchers are paying more and more attention to the ultrasonic sensor with high resolution for reliable routine thickness measurements, which is the key unit of advanced ultrasonic diagnostic apparatus for industrial system control. A new type of ultrasonic sensor with high resolution developed by the authors is reported. The technique described in this paper includes the ultrasonic sensor and the electronic block, which is the handhold microprocessor-controlled autocalibrating ultrasonic thickness gauge.

Keywords: ultrasonic sensor, transducers, sliding waves, pulses, amplifiers, microprocessor, memory, logic circuit, analog/digital converters, display, diagnostic.

1. INTRODUCTION

A major problem need to be solved is how to measure of remaining wall thickness on corroded or eroded objects, which are accessible from one side only, such as containers, tubes or machine elements, with high accuracy, then the measurement wall thickness values are to be stored in the ultrasonic thickness gauge and can be transferred to an IBM compatible PC for storage, data analysis and further evaluated for management (Krautkramer, 1986).

2. ULTRASONIC SENSOR CONFIGURATION

The ultrasonic sensor of the present paper is shown in cross-section in Fig.1. According to Fig.1., more specifically, sensor has three piezoelectric ceramic transducers, one 9 for ultrasonic pulses transmission vertically (longitudinal waves) and horizontally (sliding waves) and the other separate crystals 12, 15 for receiving returning reflections (Auld, 1973). All transducers are electrically and acoustically isolated from each other. Transmitting portion and transducers portion are separated by an electric 10 and an acoustic barrier 11. Receiving portion includes two transducers 12 and 15, which have special configuration and they coupled to a block 13,

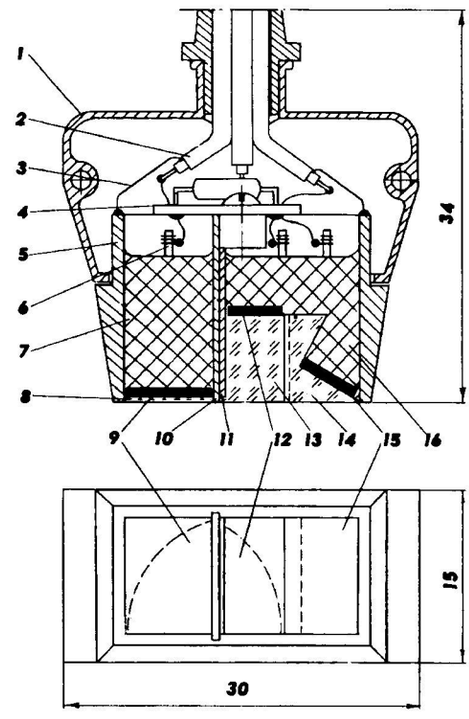

Fig.1. The ultrasonic sensor is shown in cross-section.

14 of delay material. Delay material is made of some suitable composition, typically plastic. Also included in the sensor are conventional elements and components such as a connector 10 adapted to connect to a coax cables 2 a negative lead 3, three positive leads 6 a wear surface 8 (hard contact face), a mechanical backing 7, 16 and sturdy metal housing (parts 1, 5) (DeSilets *et al.*, 1978). Transducers are operated near their natural frequencies in the range from 2,5 to 10 MHz (usual frequencies is 5 MHz).

This ultrasonic sensor with high resolution operates according to the pulse-echo principle, similar to sonar (Ermolov, 1981; Kino, 1987). The short ultrasonic pulse transmission vertically through the material until it strikes the opposite surface, where it is reflected back to the receiving crystal 12 and detected. A precise time of flight longitudinal waves measurement is used to calculate the material's thickness.

Simultaneously sliding wave is detected receiving crystal 15. The distance between transducers 9 and 15 is determined before. This way precise time of flight sliding wave measurement is used to calculate the sound velocity in materials.

3. ELECTRONIC CONFIGURATION

Further, signals from transducers 12, 15 coming to logic circuit of the electronic block for precision calculating the time elapsed between the transmitted and received pulses for measuring the thickness and the sound velocity in materials and for readings storage.

This electronic block is named the handhold microprocessor-controlled ultrasonic thickness gauge. The electronic block has a configuration shown by Fig.2. There are two exponential amplifiers, two time to voltage converters, an analog/digital converter, two type memories for storage the programs and the data files, Intel MCS®-51 microprocessor, an electric pulse generator, a synchroniser with clock generator, five registers in the electronic thickness gauge. Also included in the gauge the LCD display for displaying measured reading and for changing mode of employment, the membrane keypad for manual control, a DC power source and the serial RS-232C interface.

Low level electrical signal from transducers of the ultrasonic sensor coming to input of exponential amplifiers, such as the AD600 X-AMP® (Analog Devices). X-AMPs® are variable-gain amplifiers for which equal increments of control voltage increase the electrical signal gain in equal dB steps. For example, the control voltage increment corresponding to a 6-dB increase results in a doubling of voltage gain. Parameters of an exponential amplifier are determinating of the accuracy measure the thickness and the sound velocity in materials.

Further, signals from two time to voltage converters coming to analog/digital converter (ADC). The ICL7109 is a monolithic 12 bit ADC designed for easy interface with microprocessors. The 12 bit binary plus overrange output can be directly interfaced to a microprocessor bus. In this mode the ICL7109 is controlled by the microprocessor through the chip select and two byte enable inputs. This device offers high accuracy by lowering rollover error to less than 1 count.

The microprocessor D87C51-2 is an intellectual core of the technique described in this paper. The D87C51-2 is a highly integrated 8-bit microcontroller based on the MCS®-51 architecture (Intel, 1991). The architecture is optimised for control-oriented and real-time processing applications. The D87C51-2 contain an eight-bit central processing unit (CPU), and most operations process variables eight bits wide. All internal and external RAM and ROM, and virtually all other registers are eight bits wide. The CPU is the "brains" of the electronic block, reading the special user's program from electrically programmable internal ROM (4 Kbytes) and executing the instructions stored therein. The program memory has a sixteen-bit address bus; its elements are addressed using the program counter or instructions which generate a sixteen-bit address. The microprocessor input-output (I/O) structure is extremely versatile. The D87C51-2 has 32 I/O pins configured as four eight-bit parallel ports. Each pin will input or output data under software control. There are two sixteen-bit multiple-mode timer/counters on the D87C51-2. Its used to generate time intervals or determine pulse widths in electronic block.

The electronic block contains a high-speed, full-duplex serial port (RS-232C interface) which is software programmable to function in basic mode 8-bit UART.

Thickness and sound velocity readings can be stored in one to 99 user selectable data files accessed and displayed to select, review, edit and report data. Stored data files can also be transferred via the data output port (RS-232C) either to an IBM compatible PC for storage and data analysis or to a serial printer for a fast, hard copy report (Tompkins and Webster, 1988).

The electronic block operates on four AA NiCd batteries that are readily available and easy replaced without interrupting the readings, or losing the data logger memory.

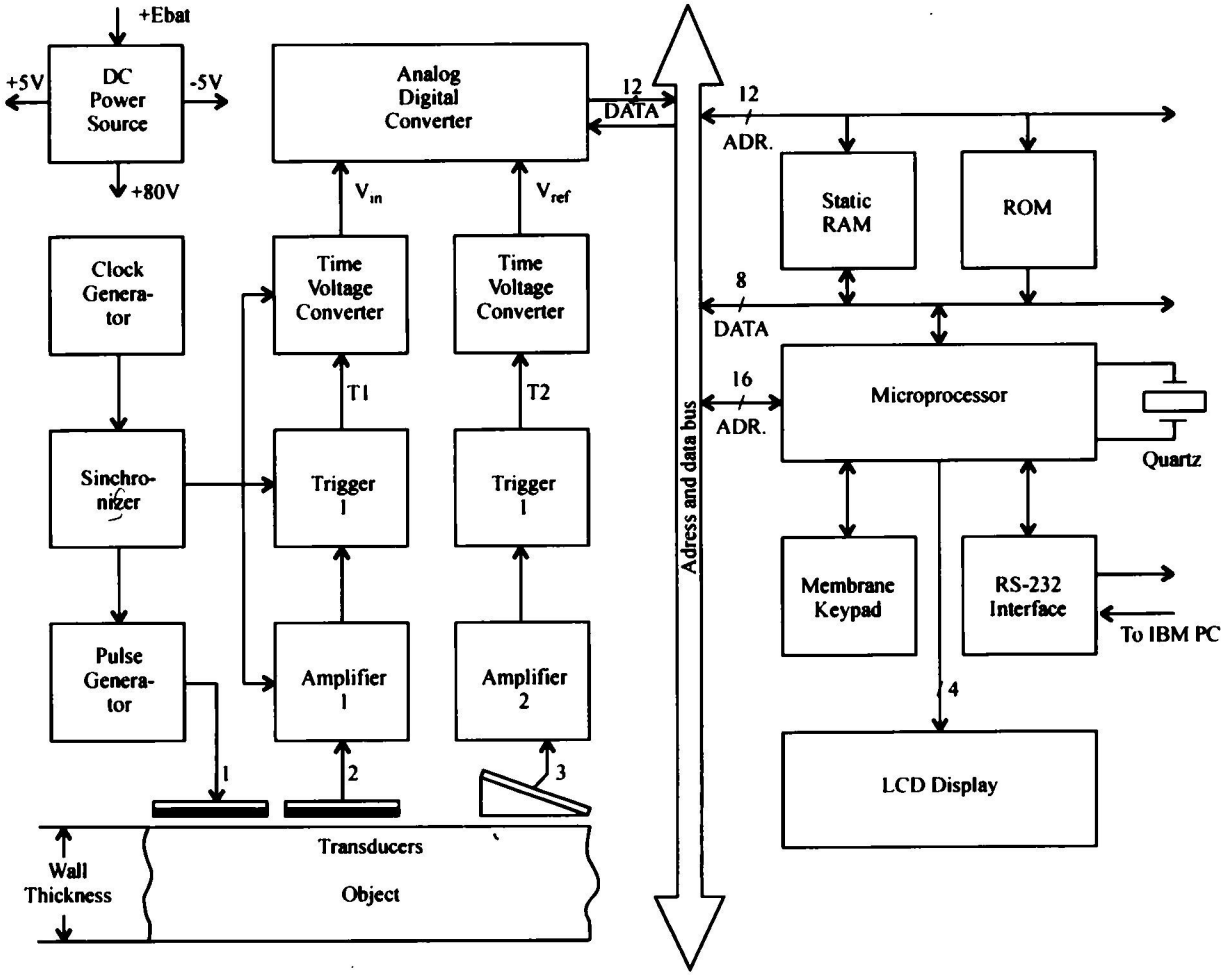

Fig.2. The block diagram of the electronic block is named handhold microprocessor-controlled ultrasonic thickness gauge.

4.SPECIFICATION OF ULTRASONIC SENSOR

Table 1 The specification of ultrasonic sensor

Parameter	Value
Operating principle	ultrasonic pulse-echo
Measuring ranges	0,8 to 200,0 mm in steel
Resolution	contact mode: 0,1 mm
Measuring units	mm, m/s
Material velocity range	1000 to 9999 m/s
Accuracy measure	thickness 0,1 mm velocity 1%
Display update rate	1 reading per 4 seconds
Display type	LCD, 4 digit, 7,5 mm high
Power supply	4 ea. 1,3 V NiCd batteries
Battery life (operating time)	up to 40 hours without charge
Auto shut-off	after 2 minutes of non-use
Data logger memory capacity	up to 980 readings, number of data files up to 99 (user selectable)
Data output port	RS 232C: serial, asynchronous, bipolar logic levels -5V, +5V, 8 bit, 1 stop bit, 9600 baud
Direct report languages	English, German
Temperature range	-10° C to +60° C
Dimensions (L*W*D)	200 mm*85mm*45 mm
Weight	0,5 kg including batteries

5. SUMMARY AND CONCLUSIONS

The ultrasonic sensor with special handhold microprocessor-controlled thickness gauge with on-board data logger provides maximum inspection versatility and efficiently management in industrial system control for wall thickness measurement, storage and management of the measurement results.

This sensor with electronic block is a portable, battery driven instrument and is suitable for mobile and stationary operation.

The ultrasonic sensor is designed for dependable performance in harsh industrial environments.

We purpose this technique as an element of an industrial system control in a shipbuilding

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