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MICROCONTROLLER DRIVEN MINIATURIZED DIGITAL DEPTH SOUNDER

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A miniaturized autonomous digital depth sounder was developed for automatic storing and recording of sea bottom depth, along with communication to various marine equipment, (chart plotter, GPS) using NMEA 0183 protocol. The analog part of the sounder consists of the miniature HEXFET transmitter and the one chip double opamp receiver. The digital part constitutes the PIC microcontroller, with a built-in analog-to-digital converter (ADC) and universal asynchronous transmitter (UART). Such an architecture allows sampling and storing the echo in compressed form in PIC's RAM memory. The UART allows transmission of the data acquired by the sounder between successive pings, via the serial line. The sounder software provides bottom tracking procedure, which can be remotely set up and reconfigured by operator. The sounder design is now under commercialization in C-MAP Group in Italy.

1. BLOCK DIAGRAM AND OPERATION OF THE SOUNDER

The block diagram of the sounder is shown in Fig. 1. Its operation is controlled by PIC16F873 microcontroller, which triggers the transmitter by sending a series of 40 pulses of 2.5 μs length onto gates of the pair of HEXFET transistors. In such a way the transmit pulse (ping) of 100μs length and 200kHz carrier frequency is generated. High voltage (around $600V_{pp}$) is obtained on the transformer output, which drives piezoelectric transducer [1].

The sounder receiver is separated from transmitter by transmit/receive (T/R) switch, which consist of two pairs of diodes protecting receiver from high voltage during transmission. After transmission of ping, the microcontroller sets the time varied gain (TVG) amplifier which controls gradually the receiver gain from 0dB to 20dB. Two opamps provide the constant gain of the receiver. The overall maximum receiver gain is around 75dB. The envelope detector constitutes the last stage of the receiver analog circuitry.

The microcontroller starts sampling the echo envelope with delay of 600μs required to dump down the transient signals resulting from transducer ringing and transmit pulse crosstalk. This time is equivalent to 0.5 m of blanking distance. For 100m nominal range, 3000 samples of 18kHz frequency are examined by the software in a time gate of 170ms.

The water temperature measurement is based on resistive properties of NTC thermistor, which output voltage is converted first to the resistance, and than to temperature. The simple algorithm employs linear approximation of the thermistor characteristics.

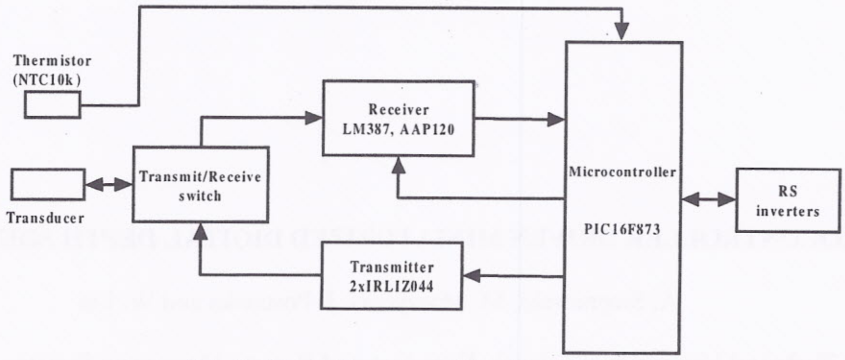


Fig.1. Block diagram of the depth sounder

The results of depth and temperature measurements are output as the NMEA tags ($SDDPT and $YXMTW) using TxD signal of RS232 protocol with the standard speed of 4800 bits/sec, what takes around 80ms (40 characters of 2ms each). The whole cycle is repeated after 80ms of break to achieve around 3 pulse per second ping rate.

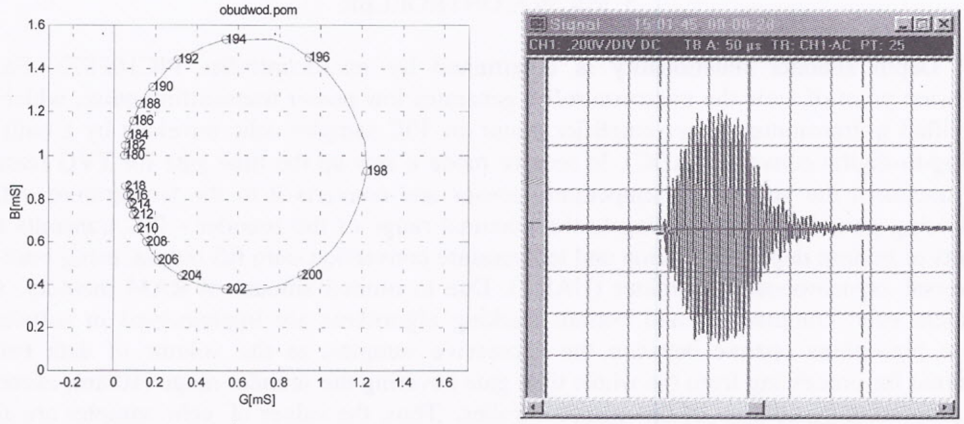
2. TRANSDUCER

Piezoceramic PZT transducer, which constitutes the crucial component of the sounder has a disc shape and is polarized to the thickness mode of vibration at the resonant frequency of 200 kHz. Transducer is isolated acoustically from its housing by cylindrical cork envelope around its side wall along with backing cork plate. The radiating area of the transducer (outer disk side) represents the negative electrode while the electrode on the inner (back) side is a positive one. The temperature sensor is placed in a hole cut out in the outer wall of the cork insulation. The transducer with its cork envelope is poured with polyurethane resin into brass housing, which simultaneously constitutes its mould in casting process. Brass housing additionally serves as an electric screen, which protects the receiver input against external noise and is connected to the PCB ground.

The vector circular diagram of the transducer admittance measured in water is shown in Fig. 2 a). As it is seen from the diagram the admittance components on the resonant frequency have the following values: conductance G=1mS, and susceptance B=0.5mS.

3. TRANSMITTER

The power amplifier of the depth sounder transmitter is build up on a pair of miniature HEXFET power transistors working alternately as current keys in extreme conditions of full conducting and cutting-off mode, which guarantee very high efficiency. Transformer on the power amplifier's output works as a transformer of low level voltage and the buffer of electric energy. The core of the transformer has high AL coefficient (AL=1600) thereby inductance of primary winding, even at small number of turns, is sufficiently high and it impairs working conditions of the power amplifier. Reactance of piezoelectric transducer has been tuned with a serial coil. Transformer ratio has been selected in order to achieve desirable output power of about 100W which corresponds to the source level of the sounder SL = 94dB [1]. Sample transmit pulse measured by hydrophone is shown in Fig. 2 b).



a) b)

Fig. 2. a) Motional admittance circular diagram of the transducer in mount loaded by water
b) Scope dump of the transmitting pulse of the sounder (500V/div)

4. RECEIVER

The receiver module of the depth sounder consists of four following blocks: transmit-receive switch (T/R), time-varied-gain amplifier (TVG), main amplifier and detector.

T/R switch consists of two pairs of diodes. First pair separates the transmitter's transformer from small echo signals, due to their high resistance for small signals received by transducer.. On the other hand, the diodes do not represent substantial resistance for strong transmitting pulses. Second pair of diodes protects the sensitive sounder's receiver against strong transmitter pulses, which are dumped on the capacitor due to its much higher impedance than conducting resistance of diodes.. For small echo signals, diodes have much larger resistance than impedance of the capacitor, and thereby they do not attenuate echoes.

TVG amplifier controls the receiver's gain in range-dependent fashion. and, in addition, also reduces the dead zone of the sounder. TVG concept is based on the polarity change of the transistor from its complete cutoff to full conducting. It results in a gradual successive increase of the gain of the receiver till its damp caused by the cutoff state.

Main amplifier has been built on a double opamp LM38, which has been chosen due to its relatively high cutoff frequency and also because it can be supplied by asymmetrical feeding. Both amplifiers have identical feedback loop creating high-pass filters. In order to reduce disturbances and noise both amplifiers are coupled together with additional high-pass filter, which increases steepness of falling part of amplifier's frequency characteristics for frequencies lower than 200kHz. The maximal overall gain of amplifier is equal 75 dB.

Envelope detector. is necessary due to low sampling frequency of the analog-to-digital converter (40kHz). Simple circuitry of diode with RC low-pass filter was applied. Operation of the detector is based on fast loading of capacitor within positive halves of high frequency signal entering the diode, for which it has a conductive character. Time constant of the low-pass filter is selected in such way that reconstructed envelope doesn't decrease after decay signal too fast. Signal from the detector output is delivered by series resistor to the input of the analog-to-digital converter (ADC) [1].

5. MICROCONTROLLER

Depth sounder functionality is determined by microcontroller PIC16F873. From hardware point of view the microcontroller generates low power transmitting pulse, which is amplified in transmitter power amplifier. Later on, PIC samples echo envelope by a built-in analog-to-digital converter (ADC). In receive mode it sets up the time gate for TVG feature and measures the voltage on temperature sensor and converts it to the temperature. After measuring period – corresponding to the maximal range of the sounder - PIC transmits the results of bottom depth calculation and temperature conversion onto RS output, using built-in universal asynchronous transmitter (UART). Due to limited amount of RAM memory, the efficient echo compression and bottom tracking algorithms are implemented in software. These algorithms operate between the successive samples, as the volume of data being acquired for processing from the whole time gate covering the sounder range (100m), exceeds the processing capabilities of the microcontroller. Thus, the values of echo samples are also available and can be output to the RS terminal (see Fig. 3). The proprietary NMEA tag (`$PCMP[`) is used for this purpose. After RS transmission microcontroller listens for special break character, and if it appears in his RS receiver, it enters its internal monitor mode. This mode allows reconfiguration of sounder functionality. For example, the user may manually change sound speed parameter or turn on algorithm of sound speed calculation using measured temparature. If flash version of PIC is used it allows even reprogramming of sounder firmware.

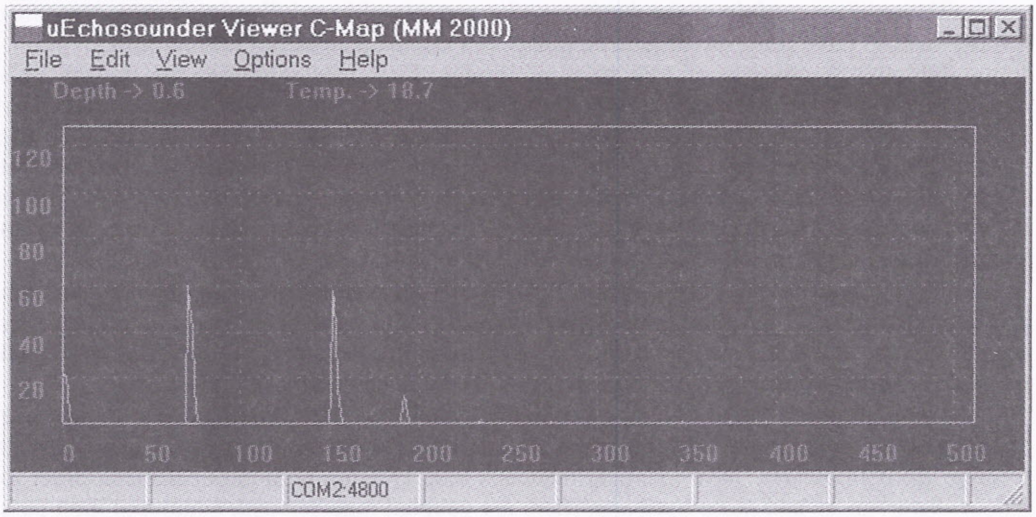


Fig 3. Sample echo acquired by depth sounder
(x-axis echo sample number, y-axis 7-bit echo sample value).

REFERENCES

1. A. Stepnowski, M. Moszyński, I. Postawka and A. Partyka, Microcontroller driven miniaturized digital echosounder, Report of the Faculty of Electronics, Telecommunications and Informatics, No. 72, Technical University of Gdańsk, 2000.