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SPECIFIC FEATURES OF DATA PROCESSING IN MICROCONTROLLER DRIVEN MINIATURIZED DIGITAL ECHOSOUNDER

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Application of the modern VLSI digital technology to the area of portable sonar equipment, like depth sounders, fish finders, short-range sonars etc., provide automatic acquisition and recording of acoustic data, along with communication with various marine equipment, like chart plotter, GPS, or even host computer, using NMEA 0183 protocol. The paper presents one such application, which constitutes the design of miniaturized microcontroller driven digital echosounder, and in particular the bathymetric data processing employed in this design. The dedicated software for such a system consists of two parts: one hard-coded in the microcontroller EEPROM memory and the other running on attached equipment. The first one uses unique features of the microcontroller, which allows real-time compression of echo data, implementation of bottom tracking algorithms and communication with host computer, while the latter in general is used for presentation of echo signals and displaying of various echogram graphics along with associate reports.

INTRODUCTION

Modern equipment uses hardware and software integration to make the design not only user friendly, but also to minimize its costs and dimensions. In this way, even small devices are equipped with a microcontroller, typically used as controlling unit. However, the development in microcontroler's technology, especially increase in the speed of operation, allows extending their application for more sophisticated tasks, performed during real-time processing. Additionally due to miniaturization of the portable designs like depth sounders, fish finders, portable echosounders, etc., they can be also used as autonomous units for precision hydrographic surveys. Moreover, if they successively deliver the acquired data to the computerized system, they constitute very versatile device.

1.GENERAL DESCRIPTION

Newly developed design of miniaturized digital echosounder uses popular 8-bit risk microcontroller from large family produced by Microchip Technology with device symbol PIC16F873 running with 8MHz clock. It has 4k of flash memory used for program code and 192 bytes of RAM memory. Sounder software uses 2k for program code from which 768 bytes are used for internal monitor with debugging functionality. The rest of memory (2k) is occupied by 40 echo records acquired on Wdzydze Lake, constituting training data set for demonstration purposes.

Whole operation of depth sounder functionality is totally determined by proper usage of microcontroller cooperating with surrounded hardware. From hardware point of view the microcontroller generates low power transmitting pulse, which is amplified in transmitter power amplifier. Later on, it samples analog echo signal obtained from the echosounder receiver. During receiving it sets up the time gate for time varied gain (TVG) signal. It also measures the voltage on temperature sensor and converts it to the temperature value. After measuring period, it transmits the results of bottom depth calculation and temperature conversion onto RS output. The operation of the software is controlled by contents of memory variables copied at start up from EEPROM memory. The parameters and settings of the sounder can be changed also during depth measurement using possibility of sending special character by RS line. The test of presence of break char in the RS receiver register is carried out during 80ms break between RS transmission and new measurement cycle. Sounder internal protocol is based on sending one letter commands to the controller. This possibility is available after entering monitor mode of the sounder. In this mode the user can enter one letter debug commands. There are implemented following commands for reading RAM registers memory (r), reading chip EEPROM memory (o), reading program memory (p). The care must be taken using equivalent writing commands (e-writing RAM memory, w-writing EEPROM memory, f-writing Flash memory) as it may easily lead to erroneous functionality.

The sounder operates by sending transmitting pulse (ping) with repetition period T_p=330ms. In software context this period can be divided into five sub-periods: 1) ping transmission, 2) delay for decay of transmitting echo to sufficiently low level, 3) sampling period, 4) NMEA transmission, 5) delay between NMEA transmission and new ping transmission. In Fig.1 the variables, which govern the timing of sounder are presented along with their default values.

Name:	*npulses*	*pulses_delay*	*nsamples*	*rs_div*	*measure_delay*
Reg.	(0x41)	(0x3F)	(0x50,0x51)	(0x40)	(0x54)
Value	40	60	3000	0x67	8
	T=40*250us	d=60*10us	t=3000*53us (sampling time)	bps=4800	8*10ms

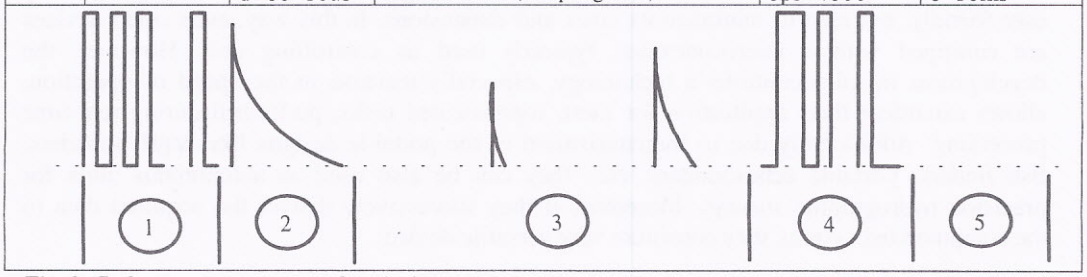

Fig.1. Software parameters for timing.

2. ECHO COMPRESSION ALGORITHM

After power-on the echosounder sends two NMEA tags reporting temperature near transducer surface (i.e. `$YXMTW,19.0,C*1A`) and bottom depth tag (i.e. `$SDDPT,0.6,*7F`). Two hex digits in the end of each NMEA sentence represent byte checksum value. Additionally, the sounder is equipped with a unique compression algorithm, which allows for storing echo samples in a 96 bytes buffer. Compression and bottom tracking algorithms operate between the successive samples (53us equivalent to 18,8kHz of sampling rate), 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. The Run Length Encoded (RLE) compression algorithm uses most significant byte for signaling number of repetition of echo data with the value below the threshold. Thus, non-zero exceeding threshold echo values are stored as the 7-bit values. As the every instruction of the microcontroller is executed precisely in 4 internal clock ticks (0.5μs) and the algorithm uses only 26 PIC instructions for every path of algorithm, it takes only 13μs. In case of buffer overflow the algorithm stops to register the rest of echo data. However, by setting up suitable sounder parameters, it is possible to automatically register bottom range. The information of echo samples are sent by using proprietary NMEA tag `$PCMP[` with two hexadecimal value for every compressed byte. Thus, one NMEA sentence does not exceed 256 bytes and it is possible to decompress data in the visualisation software run on additional equipment.

3. BOTTOM TRACKING ALGORITHM

Bottom tracking algorithm consists of the following four sub-algorithms: bottom detection, bottom windowing, "ping-to-ping" tracking and level adjustment adaptive algorithm. Bottom detection algorithm finds first echo, which exceeds bottom threshold over several numbers of samples. This simple algorithm works fine in the case when the stable echo is received. The other sub-algorithms represent more sophisticated part of bottom tracking software. Bottom windowing setups the window around the value of bottom depth found in the first stage and the "new bottom" is searched only in this window. "Ping-to-ping" algorithm requires certain number of consecutive bottom echoes to fall into the window, to be classified as the actual bottom. When the bottom is lost the last value found is output. Bottom level tracing lay in automatic decrease of bottom threshold when the new bottom echo is found in the window, but only in the case when it is found in the outer half of it. This situation may occur, when the steepness of the bottom slope increase and the received echo is most likely originated to the scattering than specular reflection. One bit in the configuration flag turns on all bottom tracking algorithms. By default only first of mentioned four algorithms is used. Turning on bottom tracking algorithms requires certain (defined) number of consecutive bottom echoes to be found and in this case the empty depth tag is sent.

4. OPTIONAL SOFTWARE

The sounder software was written in Microchip assembler, which is freely distributed by Microchip. The specialized quick and dirty version of software was also developed to make simpler communications with depth sounder. The software may be compiled into DOS version and Win32 version. The advantage of the DOS version lies in its ability to save

reprogramming of depth sounder code and waking it up after starting the system with the erroneous code. The Windows software runs as a windowed application and can display echo data and terminal communications data. It also allows changing sounder settings using dialog window (Fig.2). Only values changed in dialogs are written to sounder's memory. The visualization software was also ported to chart plotter, the device typically used in all marine vessels. It was also possible to attached host computer to such system and in this case it allows for various kinds of data display, and also for real-time redistribution in the computer network for various monitoring purposes. Using Internet software technology the dedicated Internet server software called EchoServer cooperating with WWW Server was implemented and agent code written as Java applet makes to system accessible by traditional WWW browsers.

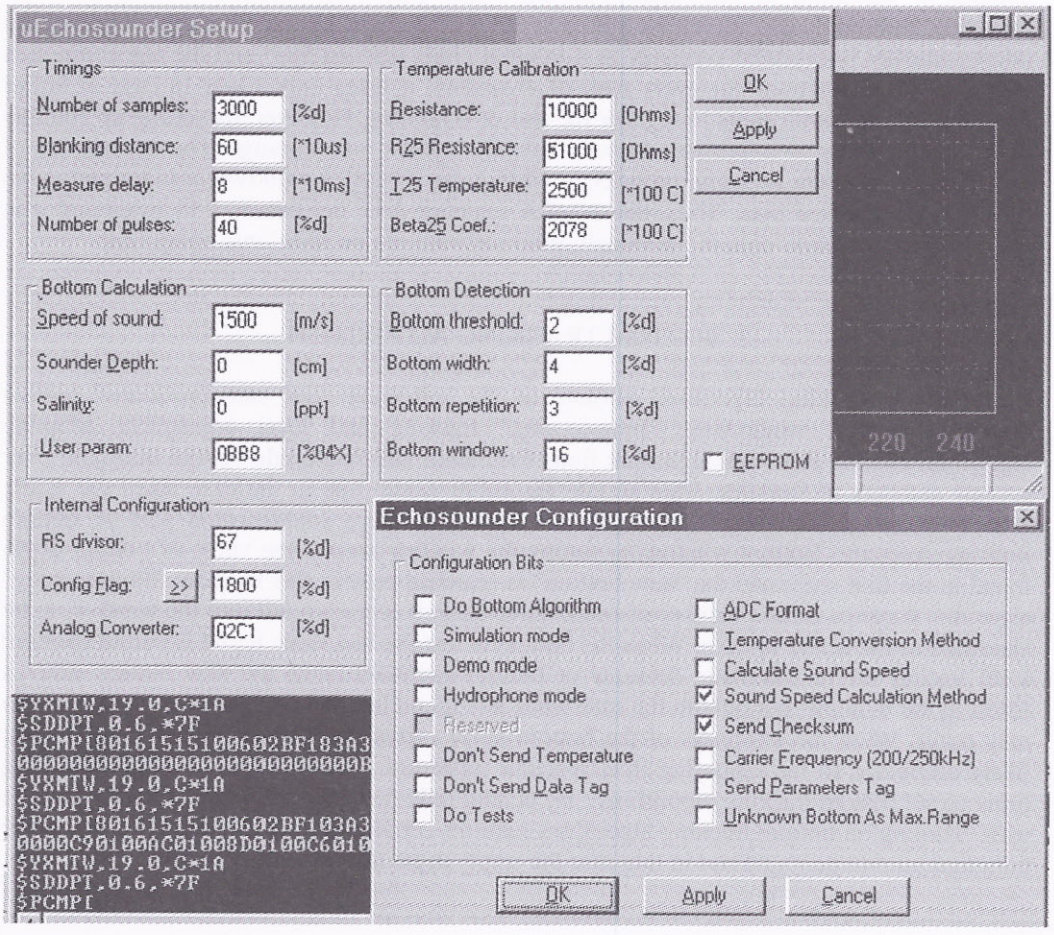

Fig.2. Dialogs in Windows software for setting up sounder parameters. An excerpt from transmission using NMEA protocol in a background window.