

Acoustic Ambient Noise Recorder

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ABSTRACT

The present-day practices of measurement and continuous monitoring of environmental parameters in oceanography utilise compact and low powered devices suitable for long periods of operation. These devices deployed in the field need to be fitted with a robust outfit that can withstand high pressures and chemically corrosion resistant materials. Keeping these considerations in view, a CMOS micro-controller-based marine acoustic ambient noise recorder has been developed with a real time clock for *in situ* measurements up to water depths of 1000 m. The architecture of the unit, pre-deployment and deployment procedures, details of field testing and the results obtained thereof from the analysis are presented. The instrument has potential applications in studies on acoustic propagation.

INTRODUCTION

Observations and experiments are crucial to the untangling of the mysteries of fluid processes, more so, of the turbulent, multiscale geophysical systems of interest to oceanographers. Here, our aim is to understand the dynamics of ocean circulation through the age-old, conventional (and reliable) descriptive practices as well as through the adoption of recent and nearly satisfactory numerical models. Basic to such understandings is the requirement of observational data (as required by the theory) on various parameters, with adequate density in space and time. This requirement resulted in the current explosion in remotely sensed oceanographic data. The possible use of sound as a method for remote measurement and monitoring of the oceans has been a long discussed idea. Munk & Wunsch [2] proposed the use of acoustics to study the ocean interior called ocean acoustic tomography.

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In ocean acoustic tomography, one is concerned with the transmission of low frequency acoustic pulse signals between a source and a receiver located within the ocean volume. One of the critical factors in identification of the received pulse(s) is the signal to noise ratio (SNR) associated with these signal(s). Information on the ambient noise levels prevailing during different seasons in any given oceanic area and their frequency components helps in interpreting the received signals and in the design of acoustic transceiver systems.

The ambient noise is the noise of the sea itself. In other words, it is the total background noise observed with an omni-directional hydrophone which contains large amounts of information about the state of ocean surface, atmosphere over the ocean (wind field), processes of the earth's crust under the ocean, behaviour of the marine animals, etc. [1,3].

Towards this end, in order to provide the necessary information on the ambient acoustic noise of the environment, a recorder has been developed. The present article deals with the architecture of the recorder - design and presents data on the recorded noise along with its analysis.

RECORDER DESIGN

Measurement and recording of data in oceanography require compact and low powered devices that are suitable for long periods of operation in the field. Keeping these considerations in mind, use has been made of CMOS (Complementary Metal Oxide Semiconductor) components which consume very little power in the design. Solid state switches—FET (Field Effect Transistors) switches—have been used rather than conventional reed-relay switches for power control operations. To make the unit compact, sizes of the circuit boards have been kept as small as possible. A real time clock (RTC) has been implemented to save power and control the timing functions of the unit.

The present system is designed to suit the general purpose hydrophone which has a depth capability of 1000 m. The electronic circuits, recorder and the battery packs have been housed in a pressure and waterproof casing.

Architecture

The functional flow diagram (Fig.1) of the noise recorder shows a microcontroller 80C31 which regulates the supply voltage to the hydrophone and the recorder separately. The underwater noise received by the hydrophone is converted into an equivalent electrical signal by the hydrophone. The hydrophone has a built-in preamplifier. The signal received by the hydrophone is amplified by a two-stage amplifier prior to its recording by the recorder.

Power consumption in the microcontroller-based recording system is minimized in the following way. The power supply to the microcontroller and other components is switched off when the system is not required to compute or record.

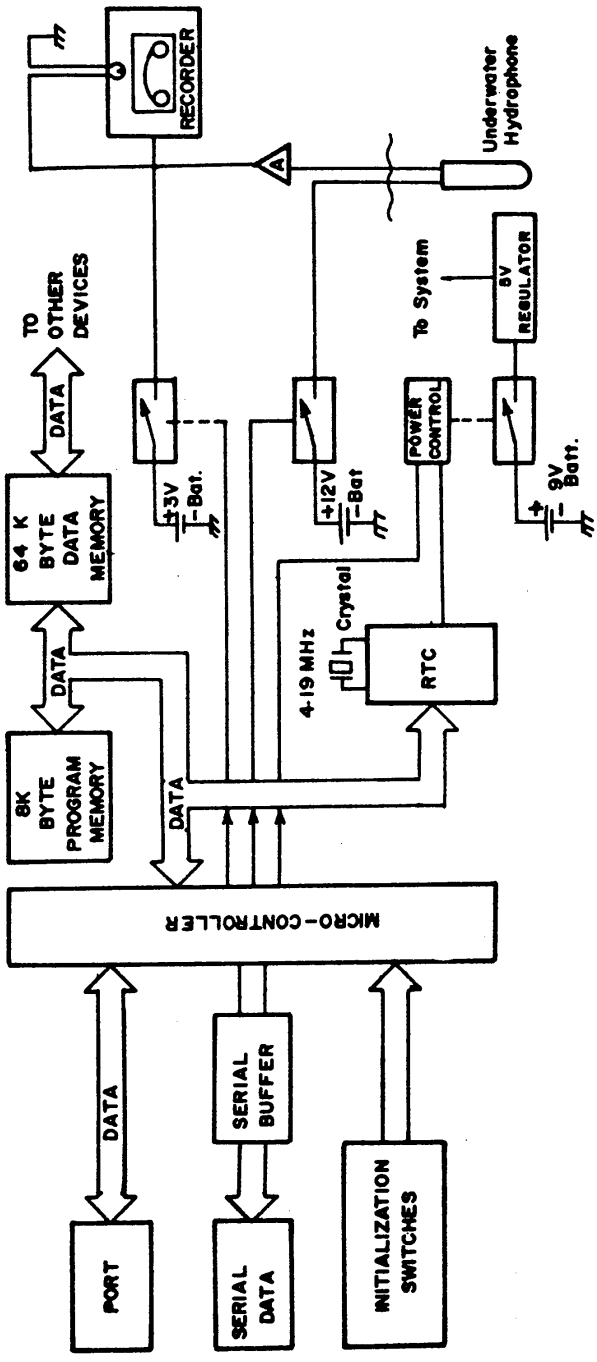


Fig.1 — System block diagram

One disadvantage here is that controller register bytes and settings are lost when power is switched off. Here, the RTC used keeps track of the time sequence and generates the alarm interrupt signal, which, in turn, activates the controller and other components. This RTC is powered all the time and hence its memory locations are utilized for storing the power down settings of the system for its systematic operation.

The instrument can be set to operate by adjusting a set of four microswitches (in front of the microcontroller) on the controller board. These switches also determine the modes of setting of the unit (Table 1). T₁, T₂ and T₃ are the time intervals (Table 1) durations which can be set by these switches. T₁ is the time interval after which the unit will start recording once the power switch is on (switched on for say 5, 30 or 60 min). This is the time required for assembling the unit prior to deployment to the required water depth. T₂ is the time duration in

Table 1 — Microswitch (SW4) Settings and Functions Required for Initializing/Operating the Noise Recorder

Switch setting position	Switch number				Micro switch function		
	1	2	3	4	T1	T2	T3
1	ON	ON	ON	ON	2 min.	1 min.	1 min.
2	OFF	ON	ON	ON	1h	5 min.	30 min.
3	ON	OFF	ON	ON	1h	5 min.	1 h
4	OFF	OFF	ON	ON	2h	2 min.	1 h
5	ON	ON	OFF	ON	2h	2 min.	3 h
6	OFF	ON	OFF	ON	2h	2 min.	6 h
7	ON	OFF	OFF	ON	2h	2 min.	12 h
8	OFF	OFF	OFF	ON	2h	2 min.	24 h
9	ON	ON	ON	OFF	2h	5 min.	6 h
10	OFF	ON	ON	OFF	2h	5 min.	12 h
11	ON	OFF	ON	OFF	3h	5 min.	1 h
12	OFF	OFF	ON	OFF	3h	2 min.	3 h
13	ON	ON	OFF	OFF	3h	2 min.	6 h
14	OFF	ON	OFF	OFF	3h	2 min.	12 h
15	ON	OFF	OFF	OFF	3h	2 min.	24 h
16	OFF	OFF	OFF	OFF	serial monitor setting		

minutes for which the system effectively records the noise. T_3 is the time duration over which the system remains idle without recording.

Hardware

The system consists of (i) a controller board and (ii) a board with regulator, amplifier and switching section.

Controller board — This consists of the microcontroller, RAM, PROM, RTC and peripheral chips. CMOS components have been used on this board. The processor used is a microcontroller 80C31 (INTEL make) with 8 k bytes program memory (EPROM) in which the micro instructions are stored which are fully responsible for the working of the entire unit. There is a real time clock chip working at a frequency of 4.194304 MHz. Data can be received/transmitted from/to input-output or expansion devices through the RS232C compatible transceiver buffer. This I/O interface is used to connect the unit to a PC for pre-deployment set up.

Board with regulators, amplifiers and switching section — Two 3-pin regulator ICs have been implanted on this board. One regulator continuously supplies 5 V to the RTC chip as long as power switch is on. The FET switch is controlled by the microcontroller input-output line which on saturation switches on the other regulator, which, in turn, supplies 5 V in the microcontroller and the memory chips. A transistor with a resistor and capacitor forms a delay circuit to hold power to the controller board for a few milliseconds after the power switch is switched on. The software then runs the initialization routine which takes care of the power subsequently.

The hydrophone amplifier is a two-stage non-inverting operational amplifier with the gain of 10 each. The total gain of 100 is achieved with 12 V power supply. There are two switching circuits each consisting of an optocoupler and FET switches, controlling the power supply to the recorder and the hydrophone. The microcontroller input-output signals are applied to the FET switches through these optocouplers, and control the FET switches for supplying power to the hydrophone and the recorder.

Software

The software flow diagram is shown in Fig.2. The unit can be setup for recording by using the serial (RS232C) interface and a PC in serial terminal mode. To achieve this, the dip switch SW4 should be set to position 15 (Table 1). The required starting time of the recorder, recording duration and time gap between two recordings are recorded using software built inside the unit. After entering the correct timings, the instrument starts functioning. If an invalid command is entered, ERROR message is displayed on the screen.

SOFTWARE FLOW CHART FOR NOISE RECORDER

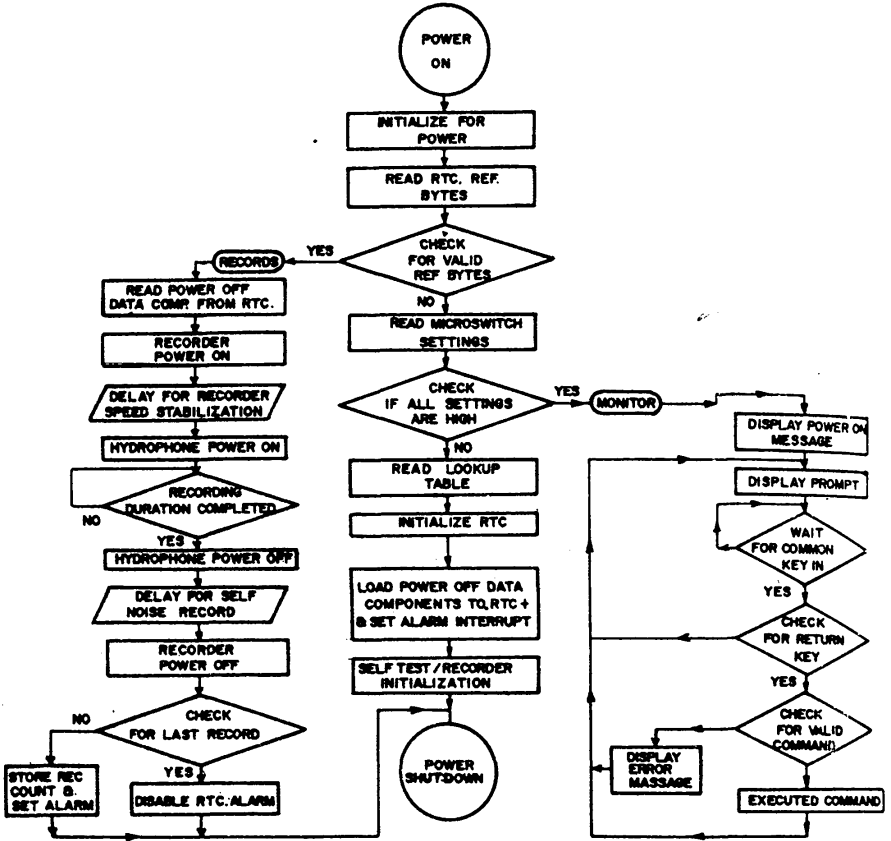


Fig.2 — Software flow chart for noise recorder

Predeployment

The hydrophone is mounted on the top of the casing. The turbulence, in the form of irregular random water movements, may shake or rattle the hydrophone in addition to the manner of mounting. During deployment, the hydrophone is fixed to the casing with the help of metal frames so as to avoid or reduce the self-noise generated and its recording as against desired ambient noise. While using a serial terminal, the microswitch SW4 should be selected to switch position 15, as shown in Table 1 and proper baud rate, parity and number of stop bits must be selected on the serial terminal (Table 2), The setup could be done using monitor commands. The recorder will then run for 5 sec, which is a self- test indicating that the switches are on and the connectors are in proper contact. The instrument is then put back into the pressure case, and C-clamps are tightened until the top

end plate rests against the edge of the pressure case. The unit with the hydrophone is now ready to be attached to the mooring frame and deployed.

Field test

The system has been made flexible to serve as a multipurpose one, so that it can be developed further with minor changes to serve as a receiving unit in any acoustic tomography field experiment. The flexibility of this unit is such that a wide variety of storage media can be used, such as E²PROM, DRAM, Digital recorder or Analog recorder. The scope of the work is highlighted in Fig.3.

Table 2 — Serial (RS 232) Interface Configuration of the Noise Recorder System

Baud rate	1200
Parity	Non
Stop bits	Two
Word length	8 bits

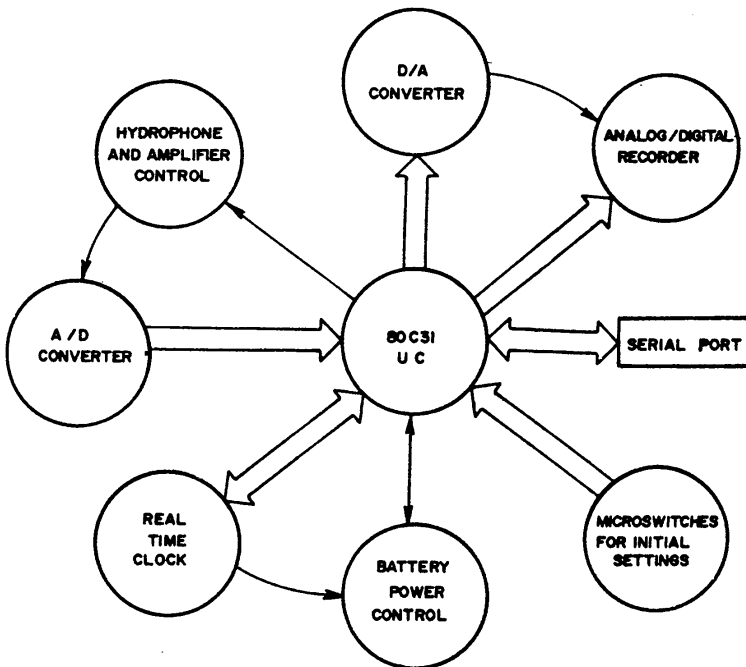


Fig.3 — Scope of the system developed

The noise recorder with its mooring frame was lowered to the river bed (water depth of 8.5 m). The sensor (hydrophone) was thus placed at a water depth of 2 m from the sea surface. The instrument was held vertical with the help of two sets of vinyl floats giving a buoyancy equivalence of 40 kg each.

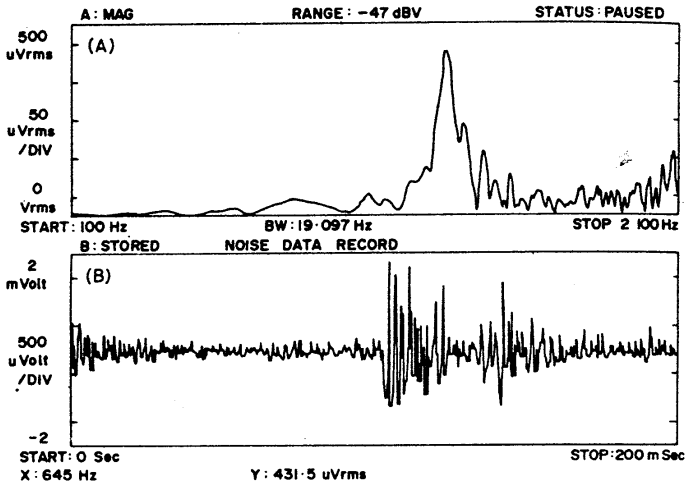


Fig.4 — Spectra showing peak at 645 Hz

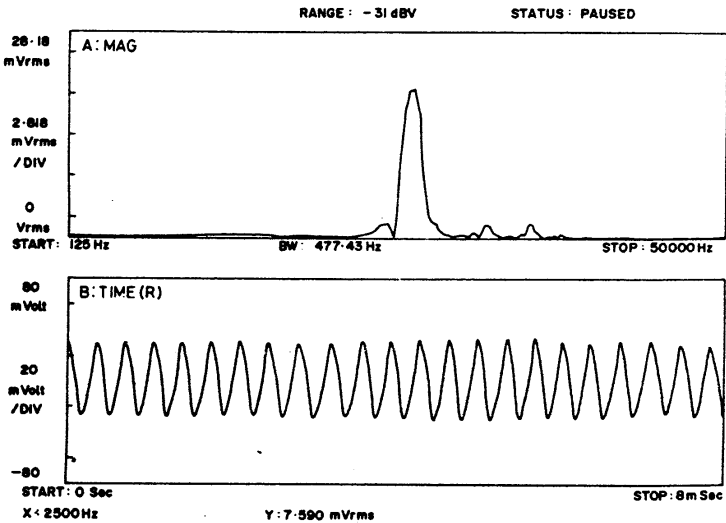


Fig.5 — Spectra showing peak at 2.5 kHz

The instrument was set to operate, so that the first noise data gets logged 20 min after the power switch was turned on (all deployment procedures were to be completed within this time). This instrument recorded four sets of data on a low noise analog cassette. each record was of 10 min duration. The time gap between successive records was set to 15 min. The instrument was retrieved after the completion of predetermined number of records.

OBSERVATIONS

The noise data recorded on the cassette was post-amplified and was fed to an audio monitor, signal analyzer (HP model 3561 A DSA) and CRO. The RMS values of the signal in the band width from 100 Hz to 10 kHz was scanned for the entire length of the cassette. This was plotted on a logarithmic scale using a digital plotter to produce the hard copy of selected intervals of noise data. The spectra (Figs 4-6) were produced by performing 1024 point FFTs of sampled data. Averages over 60 such data samples were examined.

The spectral peak at 645 Hz (Fig.4A) is due to mutual collision of the two surface vinyl floats of the mooring assembly. The wave form is shown in Fig.4B. The noise due to collision ceased after 90 ms. A continuous signal at 2.5 kHz with slowly varying amplitude was observed (Fig.5). Four spectral peaks at 3.1, 5.5, 8.3 and 11.0 kHz could be seen (Fig.6). The peak at 3.1 kHz is due to the approach of a mechanized boat about 1 km away with its propeller, rotating at 500 rpm. The

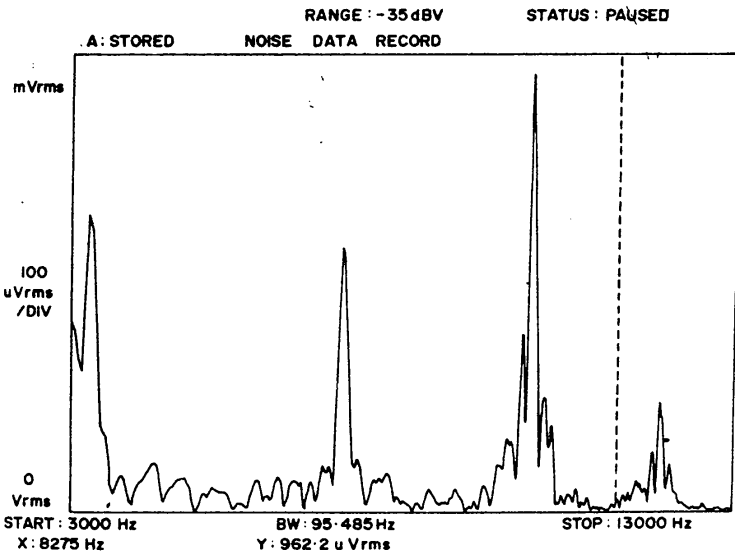


Fig. 6 — Spectra showing peaks at 3.1, 5.5, 8.3 and 11 kHz

signal level at 2.5 kHz (Fig.5) is 20 dB higher than that of the other spectral peaks. The signal levels at 5.5, 8.3 and 11.0 kHz were constant throughout the observation time and their sources of generation need identification.

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