Instrumentation for Continuous *In Situ* Monitoring of Water Quality

S. BANDYOPADHYAY, U. K. BHATTACHARYA, S. NIYOGI, P. SOM, AND D. PATRANABIS

***Abstract*—A continuous river water pollution level monitoring system using a comprehensive instrumentation package coupled with microprocessor (μP)-based data logger and telelink is described. The instrumentation package along with a power supply unit and a μP-based converter and transmitter set are housed in a floating buoy and on-shore receiving is effected through another μP-based system. A retransmission is performed next and data are received at a station sufficiently remote from the river banks, where the data are stored as well as processed for further use. Bench level tests and *in situ* experiments in lakes in the University campus have shown promising results for long term monitoring of water quality parameters of a river.**

I. Introduction

POLLUTION is largely contributed by industrial developments and population growth which occurs in proximity to water resources like rivers, large lakes, etc. A typical example is the growth of the twin cities of Calcutta and Howrah, and their industrial belts along the banks of the Hoogly river. Quality of such water resources is to be continuously monitored and controlled for maintaining an ecological balance. Most countries have taken steps to monitor and control water pollution through legislature.

The conventional system of monitoring water pollution is on an off-line basis where sampling, testing, and data logging follow in a sequence. Chemical analysis is usually adopted in such a method which, though accurate, is time consuming and is impossible to be done on an on-line basis. Long term monitoring of salt and suspended solids near the mouth of estuary of the river Mersey has been reported [1]; however, the technique adopted there cannot be called an *in situ* one as the river water is actually pumped overboard to a permanently anchored vessel for making the measurement possible.

The purpose of this paper is to present an *in situ* technique of pollution monitoring of river water using a comprehensive instrumentation package coupled with microprocessor (μP)-based data converters, loggers, and VHF transceivers. The transmitter setup, including the μP-based data converter and instrumentation package, is to be mounted in a buoy while the multiple sensors are kept dipping in the river water. An on-shore receiver, μP-based logger, and processor receive and analyze the data for future use.

The developed system was tested in the laboratory environment as well as in the lakes on the University campus and the performance of the system was considered satisfactory.

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II. The System

The proposed monitoring system is shown by the block diagram in Fig. 1. It essentially consists of two physically isolated setups: the offshore one is to be housed in a buoy floated in a river and the receiver set is kept on-shore.

The off-shore subsystem consists of 1) transducers and amplifiers, 2) a multiplexer A/D converter, 3) a microcomputer with cassette recording facility, and 4) a transceiver.

The on-shore subsystem consists of 1) a transceiver and 2) a microcomputer with printout as well as cassette recording facilities.

A. The Sensors

Electrical conductivity (EC), pH, temperature, and dissolved oxygen (DO) are the river water parameters which are to be transduced using appropriate probes. The derived electrical signals are then amplified to a level compatible with the A/D converter μP transmitter system. The probes are kept continuously dipped in water. The parameter ranges, due to diurnal and seasonal variation, are to be given consideration, and accordingly, the amplifier output ranges are to be fixed for adequate resolution.

Except for the temperature sensor, the others are based on the principle of converting water parameter into voltages which occur due to ionic imbalance, given generally by [2]

$$E = \frac{RT}{B} \ln A \tag{1}$$

where A is the parameter, B is an implicit constant being a function of ionic distribution, T is ambient temperature in degrees Kelvin, and R is the molar gas constant. The temperature sensor has the input–output relation

$$E_t = E_o \exp \frac{B}{T} \tag{2}$$

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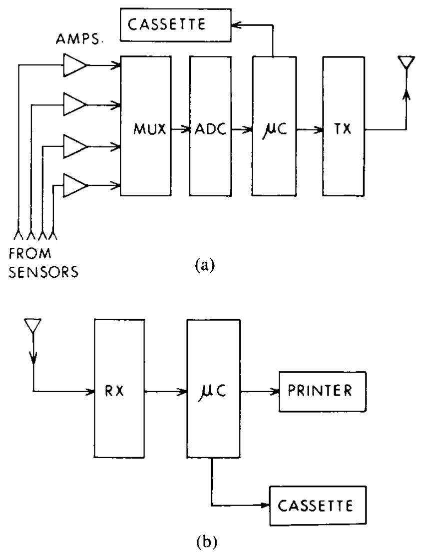

Fig. 1. (a) The off-shore subsystem. (b) The on-shore subsystem.

where B is the sensor constant and T is the measured temperature in degrees Kelvin.

Additional constraints are associated with the sensors' adaptation to the field conditions. By way of example, the conductivity cell may be considered. It usually has a bottom open glass-casing and is, therefore, vulnerable to shock loads of even a very small magnitude. Thus it requires protective shielding but must have its measuring cell volume open to the flowing water.

A protective metal sleeving with a cap-type structure (made of a metal sieve) at the bottom is a kind of solution for such adaptation. Fig. 2(a) shows a rough sketch with the adaptation. Similar protection can be arranged for the DO and pH probes. The thermistor-based temperature probe is of a different type. It uses a bead-type glass encasement thermistor which is housed in a 1/8" diameter copper tubing with bead end at the bottom side. The ends are sealed. The probe looks like the one shown in Fig. 2(b).

B. The Circuits

Commercially available circuits are for off-line use and are provided with manual range selection and standardization facilities. For on-line use such facilities are not permitted. Ambient temperature is not required to be compensated since temperature is separately monitored and may be made use of during the data processing stage. Fig. 3(a)–(d) shows the schematic circuits used with conductivity, pH, temperature, and DO probes. Grounded analog outputs for the desired ranges of parameters are obtained in these circuits. The internal oscillator of the conductivity unit is designed to generate a frequency of $6670/2\pi$ Hz to avoid noise interference and stray effects. For the pH circuit, a chopper-stabilized amplifier is used.

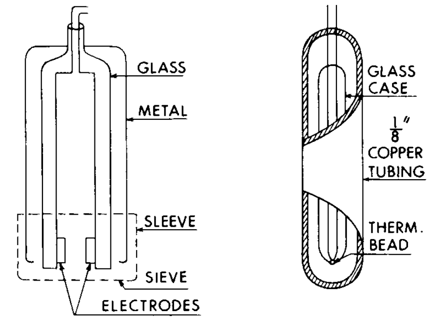

Fig. 2. (a) The conductivity probe. (b) The temperature probe.

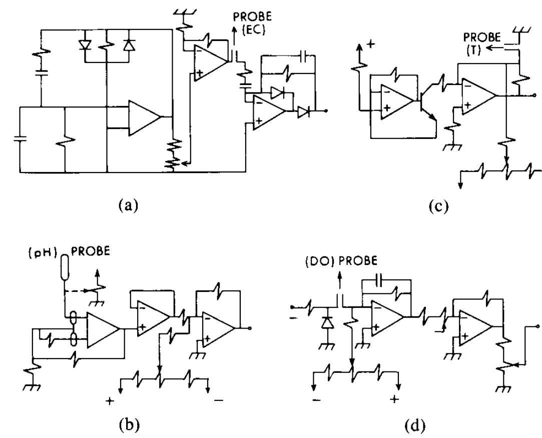

Fig. 3. (a) Circuit used with conductivity probe. (b) The pH circuit. (c) Circuit used with temperature probe. (d) Circuit for converting DO into analog voltage.

C. Multiplexer and A/D Converter

The channel selection is done by address decoding. The multiplexer is an 8-channel single-ended type receiving control from the μP. The converter converts the analog signal into a corresponding digital form. The address is latched into the decoder on the low-to-high transition of the address latch enable signal.

D. Microcomputer

The microcomputer 1) monitors the channels (4 here) periodically with a programmable time interval, 2) reads the corresponding parameter values, 3) sends them to the transmitter in a specified format, and simultaneously 4) stores them in a backup cassette.

E. Transceiver: Transmission

The devices of the first stage transceiver are in a floating buoy and used for short range communication. The setup transmits the data processed by the μP and through FM techniques to the on-shore second-stage station where retransmission will be effected using a higher range of communication.

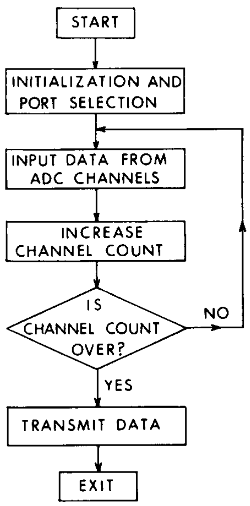

Fig. 4. Flowchart of the operation of the processor-operated transmitter.

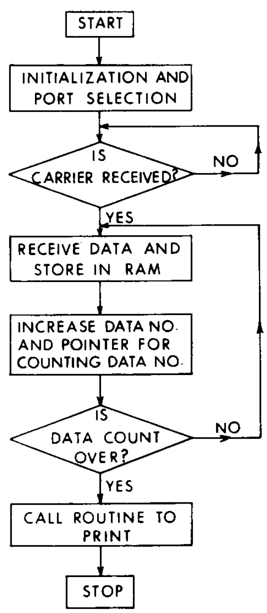

Fig. 5. Flowchart of the operation of the processor-operated receiver.

The data are transmitted by a series of variable length tone bursts whose dominant frequency can be selected to be within a passband of the particular medium. Each bit of data to be transmitted are composed of a tone burst followed by a pause. The first part of the three-part bit period is always a tone burst, the last part is always a pause, and the middle part is a pause for zero and a tone burst for one. This makes it quite distinguishable.

The square wave tone burst is generated at the serial output data pin (SOD O/P) of the processor and converted to sinusoidal form. The sinusoidal wave is then fed to a transmitter which transmits the information by phase modulation technique. At the serial input data pin (SID) of the μP the tone burst is sensed followed by a data (1 or 0) and then another pause [3]. In this manner eight such bits complete 1 byte of data. The processor operated transmission is indicated by the flowchart of Fig. 4.

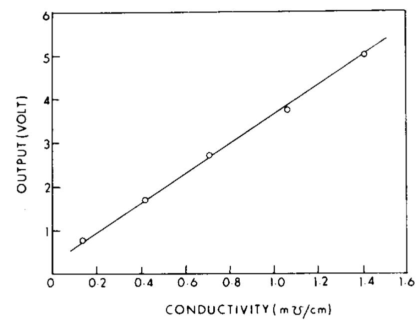

Fig. 6. Electrical conductivity versus output voltage curve.

F. Reception

The receiver performs the frequency discrimination operation for extracting the information as an audio-frequency signal. The microcomputer polls for a prescribed pattern which precedes the data set during transmission. On receipt of this pattern it starts logging the incoming data in the cassette provided for the purpose for future processing. The microcomputer operated receiver operation is shown in the flowchart of Fig. 5.

III. Experimental Test Setup

The developed system was experimentally tested in a laboratory environment and in a large lake on the University campus. The analog circuits were all mounted on a single board along with the regulated supply scheme, which was then housed in a cubicle. Probes were hung from the terminals fitted to this cubicle. The supply circuit received its input from a bank of gel-batteries. The digital equipment for the transmitter was also housed similarly and a separate supply bus was designed for them from the same batteries. Electrical conductivity, one of the four parameters monitored by the system, is shown with corresponding analog output values in Fig. 6. The analog voltages for all the parameters are transformed into digital values. At the reception side a look up table format was followed for the parameters in magnitude and unit. The results were printed and compared.

The conductivity circuit used 741 OA's, BC 148B, and 1N4001 diodes. The DO circuit used LF 356 OA's and the pH circuit used one chopper stabilized OA, 7560. ADC chips were 0808/0809 consisting of multiplexers and μP-compatible control logic. μP's were 8085-based models and transceivers were SXA portophone type and phase modulation $F3$ was used.

IV. Discussion

Extensive bench level tests were first performed to ensure accuracy and precision of the system developed. For long term performance, testing was carried out over a year covering various "tropical" seasons both in the laboratory and lake environments, using chemically prepared samples and comparing them with laboratory standards. An important aspect that needs careful consideration is the plankton and/or other live growth on the sensors immersed in polluted water. In dynamic (flowing) water this growth potential is expected to be not very severe particularly in the river estuary. In the lake water, this effect, for the period of test of 5–10 days was of not much consequence. For calibration of the DO unit, the required stirring rate as expected in the flowing river water was simulated. This was necessary as the type of the probe (Century) used required a continuous stirring at a given rate for appropriate measurement.

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