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Rapid Assessment of Ocean Environment Aided by New Shipboard STD Digitizer-Computer Interface

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As part of the new NMFS Marine Resources Monitoring Assessment and Prediction (MARMAP) Program, oceanographers are searching for key measurements to assist them in providing forecasts of the fisheries. One problem confronting these oceanographers is the rapid, accurate assessment of the ocean environment.

A recent development of interest is the linking of a Plessey Environmental Systems STD (salinity-temperature-depth) data acquisition system to a Digital Equipment Corporation PDP-8 computer[1] aboard the NMFS Northwest Fisheries Center's RV *George B. Kelez*. This involves installation of a digitizer-interface unit and has been accomplished and field-tested by personnel of the Center's Oceanography Program. Because this unit may become standard equipment aboard NMFS research vessels, a complete description is presented here.

Since the origin of reversing water bottles, salinity and temperature measurements at depth have been obtained by positioning several of these bottles (with precision reversing thermometers attached) along a cable at various depths in the ocean. Discrete water samples thus obtained were analyzed for salinity by chemical titrations or, more recently, by electronic (laboratory) salinometers. The details in the temperature and salinity structure with depth depended upon the number of Nansen bottles used. This time-consuming method has recently been supplemented by electronic sensors attached to conductor cables which, as they are lowered into the sea, give continuous analog graphical traces of the termperature and salinity profiles vs depth on recorders in the vessel's laboratory.

This analog system provides a visual display which allows oceanographers to easily locate and follow discrete strata or ocean fronts which may influence the distributions of the plankton or fish. Unfortunately, the time and personnel available for accurate analyses of data during field operations is usually limited and the extraction and correction of specific values of temperature and salinity from these graphs are not only time consuming and laborious but limit the analyses which may be done at sea. Conversion of the analog signals to digital format and processing them by computer eliminates manual processing and permits additional analyses such as field of density and geostrophic ocean currents. Our method of digitizing the signal from the Plessey Environmental System's Model 9006 or 9040 STD and interfacing the unit with a PDP-8 computer is described below.

DESCRIPTION OF HARDWARE AND FUNCTION

Hardware List

The hardware system (Figures 1 and 2) consists of: (1) the basic unit as purchased from Plessey Environmental Systems Model 9006 STD system including the underwater sensors, single conductor 1H025 cable, winch, deck unit with the three channel discriminators, and the analog graphic recorder; (2) the digitizer-interface including three Hewlett-Packard Model 5326C electronic counters, three 27-channel interconnecting cables, a Digital Input Subsystem Type DS80, and a unijunction transistor (UJT) clock of our design; and (3) a Digital Equipment Corporation PDP-8 computer with ASR35 teletype and DECtape 55 for peripheral data input-output equipment.

STD Sampling System and Analog Graphic Record

As the underwater STD unit is lowered slowly at a speed of 30 or 60 m/min to a depth of 1500 m, data are produced in an analog mode in the following manner. The sensors simultaneously produce frequency modulated (fm) signals which are linearly proportional to salinity, temperature, and depth over the respective ranges 4995 to 7901Hz = 25 to 35 $^{0}/_{00}$, 2127 to 4193Hz = −2.0 to 30°C, and 9712 to 11288Hz = 0 to 1500 m. These fm signals are mixed and transmitted through the single-conductor

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[1] Use of trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

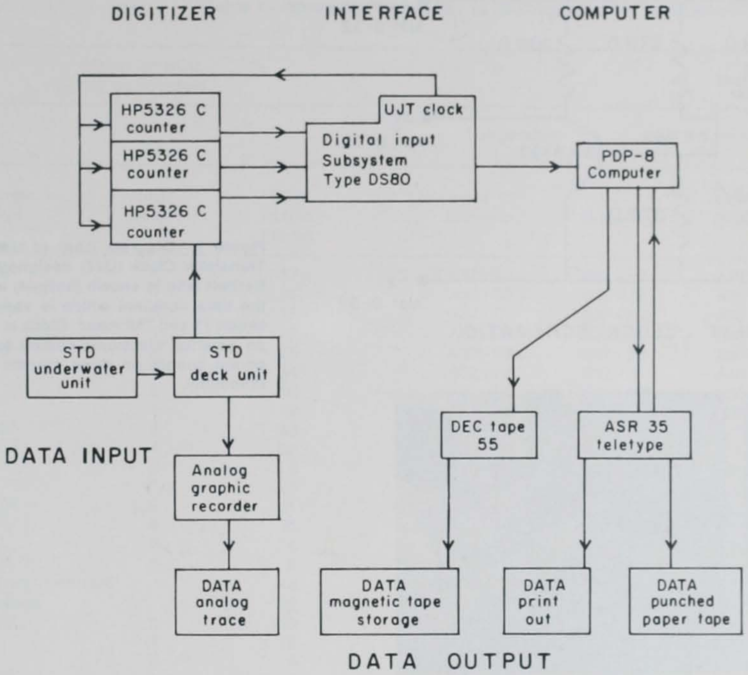


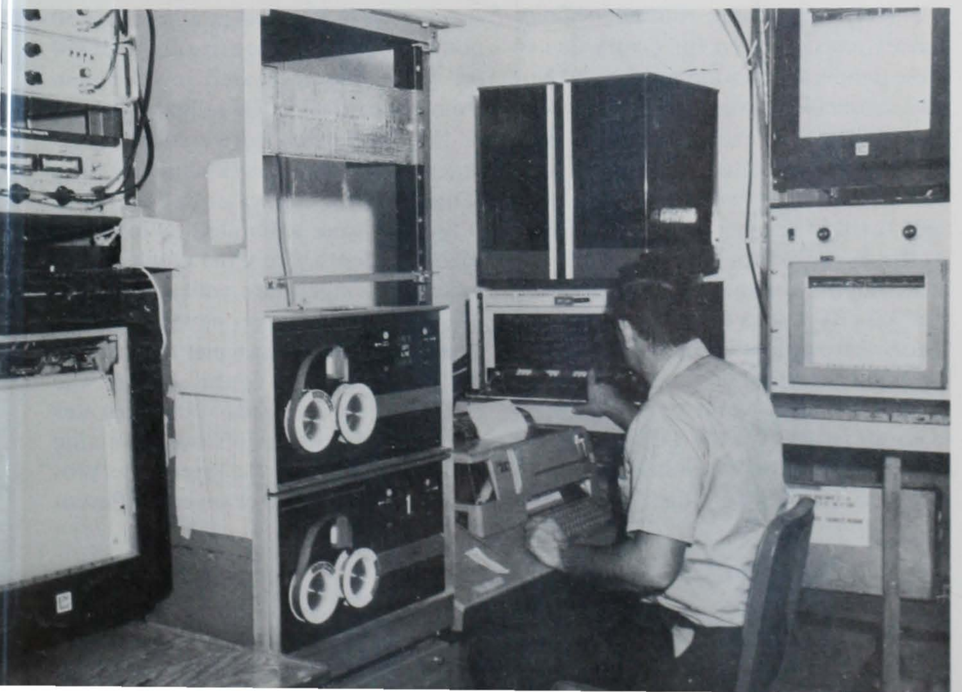
Figure 1.—Block diagram of STD-computer on-line data acquisition and processing system aboard RV ***George B. Kelez,*** **October 1971.**

cable to the deck unit where they are separated by discriminators into two branches: a 10 mv dc level or an analog fm. The former drives the X_1, X_2, Y recorder, which produces the graphic results, and the latter is sent to the computer through a digitizer/interface unit.

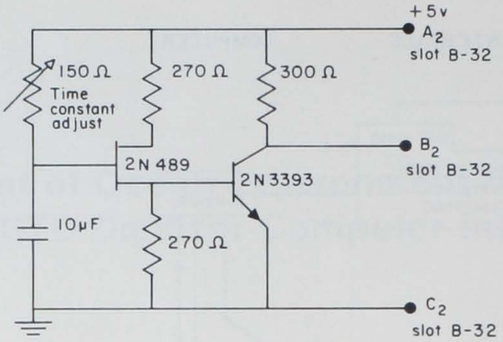
Digitizer and Data Timer

Three Hewlett-Packard electronic counters (Model 5326C) with BCD (binary coded decimal, 1-2-4-8) output option 003 and a UJT clock digitize, by period averaging, the analog fm salinity, temperature, and depth signals separately for 100 cycles. Time is measured against a 10 MHz oscillator internal time base and the result is a six-digit display available as BCD numbers in TTL (transistor transistor logic) compatible voltages for parallel wiring directly to the DS80 for computer input. Count time for each channel is slightly different—20.0200 to 12.6560 msec for salinity, 23.8490 to 47.0140 msec for temperature, and 10.2965 to 8.8589 msec for depth. This means that in a free running mode the counters will display at least 50 salinity, 21 temperature, and 97 depth readings per second; the readings could be considered instantaneous compared to the rather large time constant of 350 msec for the temperature probe. It is desirable for computational purposes, however, to have three simultaneous readings separated by a fixed time interval; thus an electronic clock was designed to control the sampling rate of the counters. The UJT clock (Figure 3) applies a +5 v to the A-6 assembly of each counter to inhibit them from counting. Timing in the clock is controlled by a resistance-capacitor circuit in which the voltage builds up until the unijunction (2N489) transistor fires. This discharges the capacitor and the process is repeated automatically at a rate which is adjustable between 75 and 750 msec. The unijunction fires a second transistor (2N3393) which pulls the output of the clock from +5 v to 0 v, thus releasing the inhibit for at least 2 μs and allowing the counters to start counting simultaneously. The maximum time to count 100 cycles is 10 msec for depth, 23 msec for salinity, and 47 msec for temperature. At the end of each count the data number is stored and held in the buffer of the counter and a print command (+5v at pin 48 of the BCD plug) is issued. Since the time for the temperature count will always be the longest, only the temperature print command is used to generate a computer interrupt as a signal all three values are available. The maximum rate of data transfer is limited by the setting of the UJT clock; 300 msec was initially cho-

Figure 2.—Laboratory arrangement aboard the RV ***George B. Kelez*** **showing C. Bartlett, electronics technician, operating PDP-8 computer which is a component of the STD computer-on-line data acquisition and processing system.**



sen. Data manipulations following each print command are software controlled.



UJT CLOCK SCHEMATIC

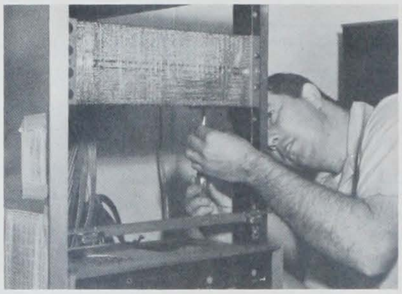


Figure 3.—Diagram (top) of Unijunction Transistor Clock (UJT) designed by C.J. Bartlett who is shown (bottom) adjusting the time constant which is variable between 75 and 750 msec. Clock is used for an external electronic control to initiate period counts on three counters simultaneously.

Digital Input Interface

A Digital Equipment Corporation Digital Input Subsystem type DS80 interfaces the digitizer and the computer. It allows software interrogation and control of digits produced by the counters. Twenty-seven parallel wires come from each counter; there are four lines for each of the six digits plus a print command, inhibit, and ground wire. A list of wire connections, between the 50 pins of the BCD connector plug on the back of the counter and the DS80 input slot-A, and rewiring of the DS80 slot-A pins to slot-B pins are shown in Table 1. In the DS80, 72 of the 96 possible contact inputs are used. These are divided into six, 12 bit data words; words 1 and 0 are temperature, words 3 and 2 are salinity, and words 5 and 4 are depth. This completes the hardware data link to the computer. Four input/output transfer (IOT) instructions provide access of any data word to the accumulator of the computer by software control.

Computer, Software, and Output

The computer system is a Digital Equipment Corporation 12 bit PDP-8 with 4K of core memory and two peripheral units, a TU 55 dual transport DECtape, and an ASR 35 Teletype which provides data storage and output on magnetic tape, punched paper tape, and paper printout. The essential features of the software program which was written in assembly language are the following. Prior to lowering the STD unit, the maximum depth, a depth printout (i.e., 2, 5, or 10 m, etc.), and a depth sampling window around the desired depth are selected (i.e., ±1, 2, or 5 m, etc.). Every 300 msec during lowering the print command from the temperature counter interrupts the computer. The program then reads the six data words and stores them in salinity temperature, and depth buffers of the core memory provided the current sample is within one of the preselected depth windows. Lowering speed is manually controlled to provide a minimum of 7 and a maximum of 127 values in each buffer. When the sensors get below the depth window, preliminary processing is performed on these data; for greater effectiveness in obtaining real time data, corrections due to calibration and gradient errors are added automatically. Conversions are made from BCD to octal numbers, then from time units to engineering units. Values are smoothed by a 3 point smoothing routine, salinity values are corrected for errors due to slow temperature compensation in thermal gradients, zero offset corrections determined for each sensor by field calibrations are added, and the final corrected values nearest the desired depth are stored in another buffer. The initial buffer is reused for the samples in the next depth window, and temperature and salinity values at the desired depth interval are output on the teletype from the final buffer when the cast depth is reached. Following the typing the same data are stored on the DECtape. The final products of this initial computer program are therefore data in the form of an analog trace and digitized values at selected meter intervals stored on magnetic tape, punched paper tape, and paper printout.

TEST RESULTS

From 15 October to 2 November 1971, 23 test lowerings were made and routine data were obtained at 32 stations off the coasts of Washington and British Columbia with the new system. The sensors were lowered at a speed of 30 m/min from the surface to a depth of 300 m; speed was increased to 60 m/min from 300 to 1500 m. Of primary interest is the agreement between the computerized data and data obtained from standard reversing water bottles.

Sensors were calibrated by lowering them to a depth where the graphic trace indicated temperature and salinity values were uniform over several meters. Then a multibottle sampler attached to the wire within 3m of the sensors was electronically actuated to obtain a water sample and readings off two reversing thermometers from the layer. This procedure was repeated at several different

Table 1.—Wiring list for counter to DS80 input cables and internal pin to pin wiring added to DS80.

Wiring for BCD plug on counters			DS80 internal wiring					
			Temperature		Salinity		Depth	
Counter digit	BCD weight	BCD output Pin No.	Input Slot$_1$-Pin$_1$	Slot$_2$-Pin$_2$	Input Slot$_1$-Pin$_1$	Slot$_2$-Pin$_2$	Input Slot$_1$-Pin$_1$	Slot$_2$-Pin$_2$
10^5	8	37	A32 - A2	B32 - E2	A30 - A2	B26 - E2	A28 - A2	B20 - E2
	4	36	A32 - B2	B32 - J2	A30 - B2	B26 - J2	A28 - B2	B20 - J2
	2	12	A32 - C2	B32 - N2	A30 - C2	B26 - N2	A28 - C2	B20 - N2
	1	11	A32 - D2	B32 - S2	A30 - D2	B26 - S2	A28 - D2	B20 - S2
10^4	8	35	A32 - E2	B31 - E2	A30 - E2	B25 - E2	A28 - E2	B19 - E2
	4	34	A32 - F2	B31 - J2	A30 - F2	B25 - J2	A28 - F2	B19 - J2
	2	10	A32 - H2	B31 - N2	A30 - H2	B25 - N2	A28 - H2	B19 - N2
	1	9	A32 - J2	B31 - S2	A30 - J2	B25 - S2	A28 - J2	B19 - S2
10^3	8	33	A32 - K2	B30 - E2	A30 - K2	B24 - E2	A28 - K2	B18 - E2
	4	32	A32 - L2	B30 - J2	A30 - L2	B24 - J2	A28 - L2	B18 - J2
	2	8	A32 - M2	B30 - N2	A30 - M2	B24 - N2	A28 - M2	B18 - N2
	1	7	A32 - N2	B30 - S2	A30 - N2	B24 - S2	A28 - N2	B18 - S2
10^2	8	31	A32 - P2	B29 - E2	A30 - P2	B23 - E2	A28 - P2	B17 - E2
	4	30	A32 - R2	B29 - J2	A30 - R2	B23 - J2	A28 - R2	B17 - J2
	2	6	A32 - S2	B29 - N2	A30 - S2	B23 - N2	A28 - S2	B17 - N2
	1	5	A32 - T2	B29 - S2	A30 - T2	B23 - S2	A28 - T2	B17 - S2
Print Command		48	A32 - U2	B32 - U2				
Inhibit		22	A32 - V2	B32 - B2	A30 - V2	B32 - B2	A28 - V2	B32 - B2
10^1	8	29	A31 - A2	B28 - E2	A29 - A2	B22 - E2	A27 - A2	B16 - E2
	4	28	A31 - B2	B28 - J2	A29 - B2	B22 - J2	A27 - B2	B16 - J2
	2	4	A31 - C2	B28 - N2	A29 - C2	B22 - N2	A27 - C2	B16 - N2
	1	3	A31 - D2	B28 - S2	A29 - D2	B22 - S2	A27 - D2	B16 - S2
10^0	8	27	A31 - E2	B27 - E2	A29 - E2	B21 - E2	A27 - E2	B15 - E2
	4	26	A31 - F2	B27 - J2	A29 - F2	B21 - J2	A27 - F2	B15 - J2
	2	2	A31 - H2	B27 - N2	A29 - H2	B21 - N2	A27 - H2	B15 - N2
	1	1	A31 - J2	B27 - S2	A29 - J2	B21 - S2	A27 - J2	B15 - S2
Ground		50	A31 - K2	B31 - C2	A29 - K2	B29 - C2	A27 - K2	B27 - C2

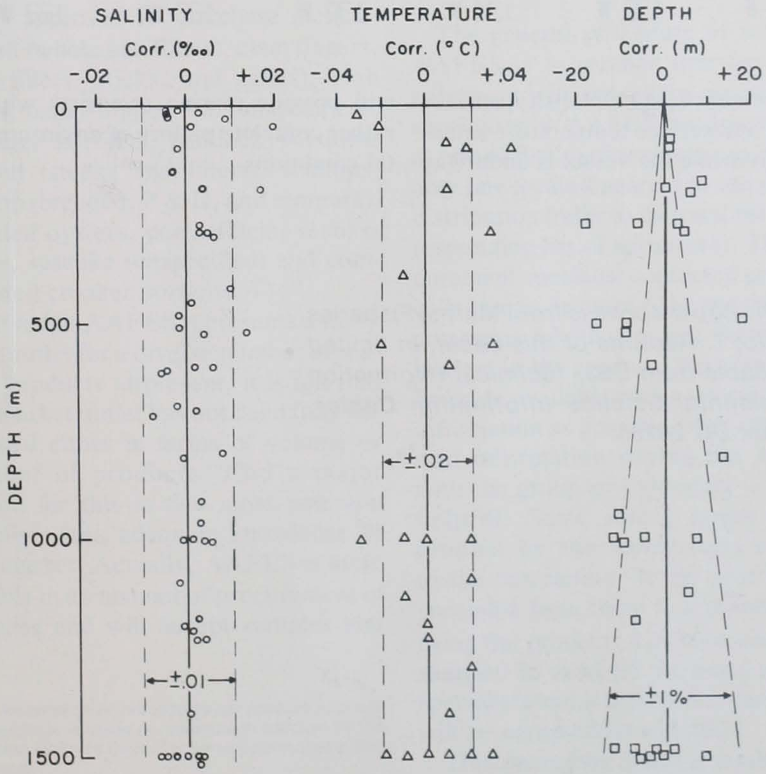
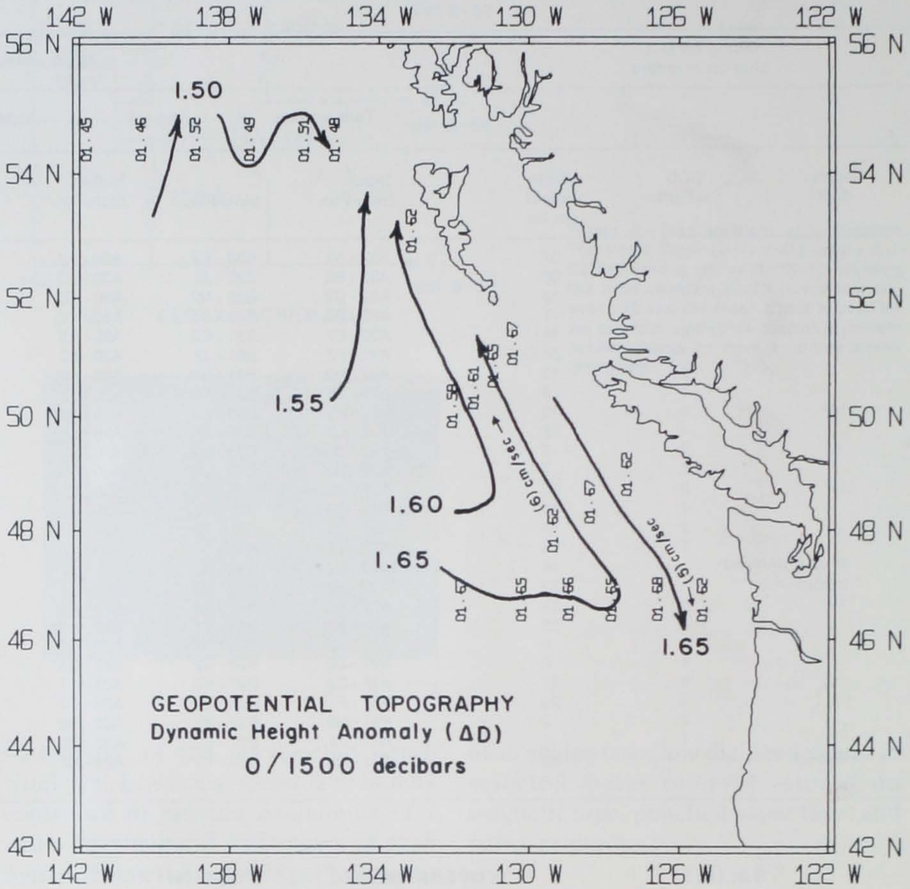


Figure 4.—Comparison of STD-computer produced data with simultaneous data from Nansen bottles. The plots of computer corrections vs depth show that the precision of the data from the shipboard system compares favorably within a factor of 2 to 3 around the standard accuracy ranges expected from Nansen bottle data.

Figure 5.—Surface geostrophic currents computed from salinity, temperature, and depth data collected during October test cruise. This illustration shows one way of presenting the environmental information for analysis for later comparison with fisheries data.



depths when weather conditions were good, and at least one calibration point was obtained at each station throughout the cruise to detect any shift in calibration with depth or any change with time. Water samples were analyzed aboard for salinity by precision laboratory salinometers, and thermometers were corrected by standard techniques. Comparison of computed data with data from water bottles and reversing thermometers at the calibration points indicated a close agreement of temperature values within about ±0.02°C, of salinity values within about ±0.01 ‰, and of depth values within about ±1% (Figure 4). This is quite an acceptable error especially considering that this method of comparison assumes no error in the data from reversing water bottles which may normally be expected to vary at best ±.01°C, ±.003 ‰ , and ±.5%.

In view of the success of this system which provides rapid, accurate STD data, other sensors such as dissolved oxygen will also be interfaced to the computer. Later in the total MARMAP operational mode, various devices which measure chemical nutrients, water fluorescence, light intensity, surface salinity, and surface temperature simultaneously while the vessel is underway will provide marine scientists with a rather complete picture of environmental conditions.

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