Modification of EG&G Vector Averaging Current Meter to record light transmission and water conductivity

by

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INTRODUCTION

An EG&G model 610C Vector-Averaging Current Meter (VACM) (AMF Sea Link, 1976) has been modified to record light transmission, water conductivity, and temperature data, in addition to the standard VACM parameters. The original circuit design and modification to the initial VACMs was done by Sea Data Corp. of Newton, Mass. Subsequent VACM modifications have been performed by USGS personnel using circuit boards purchased from Sea Data. The instrument, which is called a VACM-TCT for transmission-conductivity-temperature is deployed in a subsurface mooring. It has been used to investigate the dynamics of currents and sediment movement on the Atlantic Continental Shelf and Slope along the east coast of the United States. This paper briefly describes the sensors, the sensor mounting, the data format, and the circuitry of the VACM-TCT.

SENSORS

The transmissometer measures light transmission, a measure of the suspended-matter concentration in the water column, over a 25-cm path length (fig. 1). The light source is a collimated red light emitting diode (LED). The output of the sensor is a positive direct current (dc) voltage (0-5 vdc) that is proportional to the light measured at the detector. The transmission sensor is manufactured by Sea Tech, Inc. and is described in detail in Bartz and others (1978).

The sensing element of the conductivity meter is a 2-terminal, 3-electrode flow-through cell (fig. 1). The resistance measured between the center electrode and the outer pair is determined by the cell geometry and the specific conductance of the fluid within the cell. The cell resistance is used to control the output frequency of a Wien Bridge. The output frequency of the conductivity sensor is 7-11 kHz for 20-50 millimho (mmho). The conductivity sensor is manufactured by Sea Bird Inc. and is described in detail in Peterson and Gregg (1979).

The temperature-sensing element is a passive probe, 30-kilohm thermistor (fig. 4). The probe, which is placed directly in the water flow, has a response time of about 0.1 s. In contrast, the standard thermistor that is mounted in the lower end cap of the VACM has a response time of 200 seconds because of the thermal mass of the case and mounting plate. The temperature measured by the fast-response externally mounted thermistor and the conductivity measurement are used to compute water salinity. The output of the thermistor is a positive dc voltage that is proportional to temperature.

CIRCUIT BOARDS AND SENSOR MOUNTING

Five circuit cards are required to modify a standard VACM so that it can measure and record transmission, conductivity, and fast-response temperature. The cards are installed in slots located at the upper portion of the card rack. The additional cards and their function are listed in table 1. The mechanical arrangement of the circuit cards in the VACM-TCT is shown in figure 2.

The transmissometer is mounted horizontally to minimize fouling due to any settling of material on the optical windows. Cages around the sensors
protect them from damage during launch and recovery. The sensors are attached to the VACM case by one split-ring clamp. Figure 1 shows the transmissometer and conductivity sensors and their individual mounting brackets. Figure 3 shows the sensors mounted in their brackets and the TCT-mounting bracket. Figure 4 is a photograph of the completely assembled VACM-TCT with cabling.

All incoming wires enter the VACM pressure case via a feed-through penetrator in the lower end cap. This penetrator is of the same mechanical configuration as the penetrator used for the Sony diode (see fig. 5).

DATA FORMAT, CAPACITY, AND CONVERSION

The data record of the VACM is expanded by 48 bits to incorporate the three additional variables. The arrangement of the data record for a VACM-TCT is listed in table 2. The addition of three 16-bit words to the VACM data record reduces the tape capacity by approximately 18 percent. The data capacity (in days) for the modified instrument as a function of recording interval and tape length is listed in table 3.

The decimal count recorded by the VACM-TCT is converted to engineering units in the following way:

Temperature:

\[
M = \text{Counts}/8192 \\
RT1 = M/136280 + 1/144040 \\
RT = 1/RT1 - 50000 \\
TA = A + B \log RT + C (\log RT)^3 \\
\text{Temp} = 1/TA - 273.15°C
\]

Default values: \(A = 9.07 \times 10^{-4}\); \(B = 2.253 \times 10^{-4}\); \(C = 1.136 \times 10^{-7}\)

Transmission: Voltage = (Counts/8192)(5) volts

Conductivity: Frequency \((f) = \text{Counts}/1.7578 \text{ Hz} \\
\text{conductivity} = \frac{f^2}{(a-bf^n)^2} + cT \text{ mmho}
\]

where \(a\), \(b\), \(c\), and \(n\) are calibration constants for each sensor. For example, \(a = 1491.89\), \(b = 2.25 \times 10^{-19}\), \(c = 9.0 \times 10^{-6}\), and \(n = 4.72\) for sensor #51.

TIMING, CONTROL, AND POWER

The outputs of the transmission, conductivity, and temperature sensors are sampled once for 1.7578 seconds in the middle of the VACM sampling interval. All references to card slots and pin assignments, such as J22P13,
can be found in figures 6 and 8. All card and pin assignments for J1 through J19 are in the VACM users manual (AMF, 1976). Figure 6 shows the timing sequence of the TCT parameters and figure 8 shows the backplane wiring. The basic timing pulses are supplied by the VACM clock card at a frequency of 1.1378 Hz (J10P9).

On the rising edge of the mid-interval signal (J6P2), the "Event" signal (J21P20) is turned on for 7.47 s. This signal is sent to two places: It applies power to the frequency multiplier (J22P13), which sends the reference frequency to both A/Ds, and it applies power to all the sensors by enabling the 10.3-vdc "Power Out" (J25P31), which powers the transmissometer and the conductivity sensors. "Power Out" also enables (J23P22) the 6-vdc power to the thermistor. "Counter Reset" (J21P24) occurs 2.197 seconds later and resets the data counters on all cards. "Start B" (J21P25) occurs 0.8789 seconds later (3.08 seconds after Power On). This signal enables the "B" (J21P12) clock which enables all counters. "Stop B" (J21P27) disables all the counters from further input after 1.7578 seconds, which is the data sampling interval.

Power for the circuit cards is drawn from the +13-vdc regulated supply of the VACM. During the off period, the additional circuit cards draw less than 0.1 milliamp (ma). During the 7-second sampling period, the cards and sensors draw a total of about 20 ma. The transmissometer sensor draws about 10 ma and the conductivity sensor about 8 ma. The total power requirements are thus about 2.76 amp-hr for a 150-day deployment (sampling every 3.75 min) and 3.12 amp-hr for a 300-day deployment (sampling every 7.5 minutes). This is 13 percent and 15 percent at the +13-vdc supply, respectively.

WIRING AND BACK PLANE

The wiring diagram for the external TCT cable is shown in figure 7. The backplane wiring and card schematics for the VACM-TCT modification are shown in figures 8-16.

REFERENCES CITED
AMF Sea Link, 1976, Vector averaging current meter model 610C, users manual: EG&G Sea Link, Herndon, VA.
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<th>Card Slot</th>
<th>Function</th>
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<tr>
<td>25</td>
<td>Conductivity - XP-35. This card conditions the conductivity signal and counts the conductivity signal frequency. See figures 9 and 10 for card details.</td>
</tr>
<tr>
<td>24</td>
<td>Transmissometer Integrating A/D - DC-37-4. This card is a 0-5 vdc integrating A/D for the LED transmissometer. See figures 11 and 12 for card detail.</td>
</tr>
<tr>
<td>23</td>
<td>Temperature Integrating A/D - DC-37-8. This card is the 0-35°C integrating A/D for the fast response thermistor. See figures 13 and 12 for card detail.</td>
</tr>
<tr>
<td>22</td>
<td>Frequency multiplier - WC-38. This card provides the reference frequency used for the integrating A/Ds. See figure 14 for card detail.</td>
</tr>
<tr>
<td>21</td>
<td>Sequence control card - BC-30. This card provides the timing sequence signals for sampling the TCT parameters. See figures 15 and 16 for card detail.</td>
</tr>
</tbody>
</table>
Table 2. Data format

<table>
<thead>
<tr>
<th>Description</th>
<th>Length</th>
<th>Bit Position</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>East vector</td>
<td>24</td>
<td>1-24</td>
<td>3 MSB always zero</td>
</tr>
<tr>
<td>North vector</td>
<td>24</td>
<td>25-48</td>
<td>3 MSB always zero</td>
</tr>
<tr>
<td>Rotor count</td>
<td>24</td>
<td>49-72</td>
<td>3 MSB always zero</td>
</tr>
<tr>
<td>Compass heading</td>
<td>8</td>
<td>73-80</td>
<td>MSB always zero</td>
</tr>
<tr>
<td>Vane heading</td>
<td>8</td>
<td>81-88</td>
<td>MSB always zero</td>
</tr>
<tr>
<td>Time</td>
<td>16</td>
<td>89-104</td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>24</td>
<td>105-128</td>
<td>21 significant bits</td>
</tr>
<tr>
<td>F.R. temperature</td>
<td>16</td>
<td>129-144</td>
<td>13 significant bits</td>
</tr>
<tr>
<td>Transmission</td>
<td>16</td>
<td>145-160</td>
<td>13 significant bits</td>
</tr>
<tr>
<td>Conductivity</td>
<td>16</td>
<td>161-176</td>
<td></td>
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Table 3. Data capacity

<table>
<thead>
<tr>
<th>Recording interval</th>
<th>Tape capacity in days 300' tape</th>
<th>Tape capacity in days 450' tape</th>
</tr>
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<tr>
<td>3.75 min</td>
<td>120</td>
<td>174</td>
</tr>
<tr>
<td>7.50 min</td>
<td>240</td>
<td>347</td>
</tr>
<tr>
<td>15.00 min</td>
<td>479</td>
<td>695</td>
</tr>
</tbody>
</table>
NOTES:
1. INDIVIDUAL CONDUCTORS MUST BE WATER BLOCKED IN THE PENETRATOR.
2. ASSEMBLY MUST BE CAPABLE OF WITHSTANDING SEAWATER PRESSURES OF 10,000 PSI WITHOUT LEAKING.

MATERIAL - 6061-T6 ALUM. HARDCOAT .001/.002 PER MIL. A-86ZS DIMENSIONS APPLY BEFORE HARDCOAT

PENETRATOR ASSEMBLY
VACM

DRAWING 9.1 NOV. 22, 1983
1.1378 Hz Clock

Mid-Interval

Event

Counter Reset

Start 'B'

'B'

Stop 'B'

Power Out

TIMING DIAGRAM

Figure 6
SYSTEM CABLE DIAGRAM

Figure 7
Changes to J11
(CR-30 control card to make
44 character data record instead of 32).
move 12 to 5
move 14 to 15

Changes to J13
(CR-30 control card to make
44 character data record instead of 32).
move 12 to 5
move 14 to 15

Figure 8

Sea Data VACM Modification
Sea Bird Conductivity
Fast Response Temperature
Sea Tech LED Transmission

For U.S. Geological Survey, Woods Hole, MA
1980
Figure 10
Figure 11
Figure 13
Notes:
1) SIP Array - 3.3M
2) IC1 can be RCA 4046 but then 0.5 sec rate multiplier is limited to 16X and FMAX to 850 KH:
   R3 = 4.7K and move IC9P13 to IC10P6.

WAVE BURST POWER
HI FOR ENABLE

WAVE CONTROL
PLL
NO. WC-38

Figure 14
DELAY TIMER DELAY TIME \( T_d \) MEASURED FROM "START" TO "EVENT" (SEQUENCE STATES) \( T_d \), EXACT TIMES WHEN \( n = 0 \), \( T_d = 0.5T \) AND WHEN \( n > 0 \), \( T_d > T \) WHERE \( X \) IS RANGES FROM \( \frac{1}{2}T \) TO \( \frac{1}{2}T \) AND IS LARGE ENOUGH TO SATISFY: \( (k + \frac{1}{2})T \leq X \leq (k + \frac{1}{2})T \) WHERE \( K \) IS AN INTEGER.

FORMULAS ASSUME INPUT CLOCKS \( T \) AND \( T_2 \) AND START ARE DERIVED FROM ONE NARY DIVIDER.

SEQUENCE TIMER DELAY AND 8 STATES AND 3 FF'S BC-30

Figure 15