UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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:

$$M = \text{Counts}/8192$$

$$RT1 = M/136280 + 1/144040$$

$$RT = 1/RT1 - 50000$$

$$TA = A + B\,(\text{Log } RT) + C\,(\text{Log } RT)^3$$

$$\text{Temp} = 1/TA - 273.15^{\circ}C$$

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) = Counts/1.7578 Hz

$$\text{conductivity} = \frac{f^2}{(a-bf^n)^2} + cT^2 \text{ mmho}$$

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.

Bartz, R., Zanefeld, J. R. V., and Pak, H., 1978, A transmissometer for profiling and moored observations in water: Proceedings, Society of Photo-Optical Instrument Engineers, v. 160, p. 102-108.

Peterson, A. M., and Gregg, M. C., 1979, Development of a small _in situ_ conductivity instrument: Institute of Electrical and Electronics Engineers, Journal of Oceanographic Engineering, OE-4, p. 69-75.

Table 1. Circuit-board description

Card Slot	Function
25	Conductivity - XP-35. This card conditions the conductivity signal and counts the conductivity signal frequency. See figures 9 and 10 for card details.
24	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.
23	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.
22	Frequency multiplier - WC-38. This card provides the reference frequency used for the integrating A/Ds. See figure 14 for card detail.
21	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.

Table 2. Data format

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

Table 3. Data capacity

Recording interval	Tape capacity in days 300' tape	450' tape
3.75 min	120	174
7.50 min	240	347
15.00 min	479	695

Figure 1

Figure 2

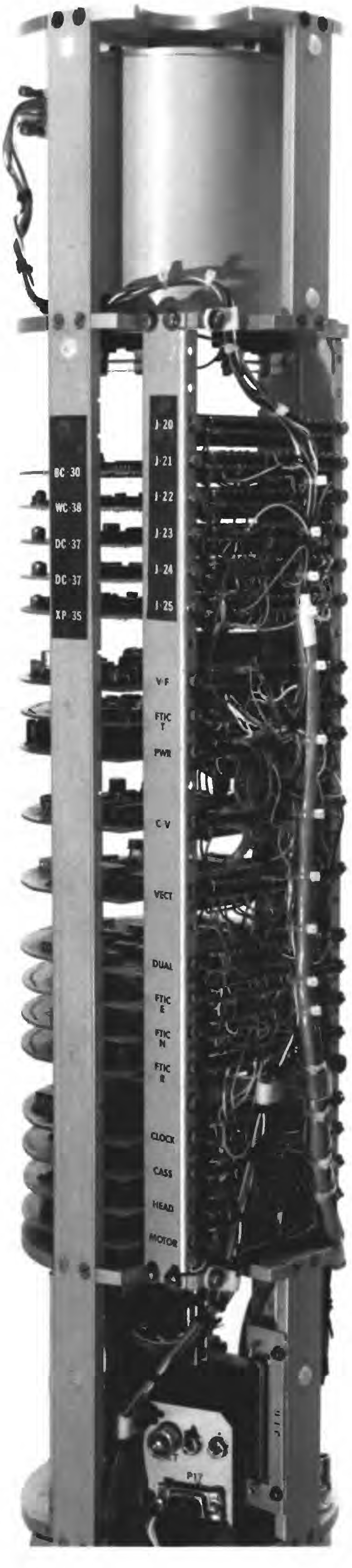
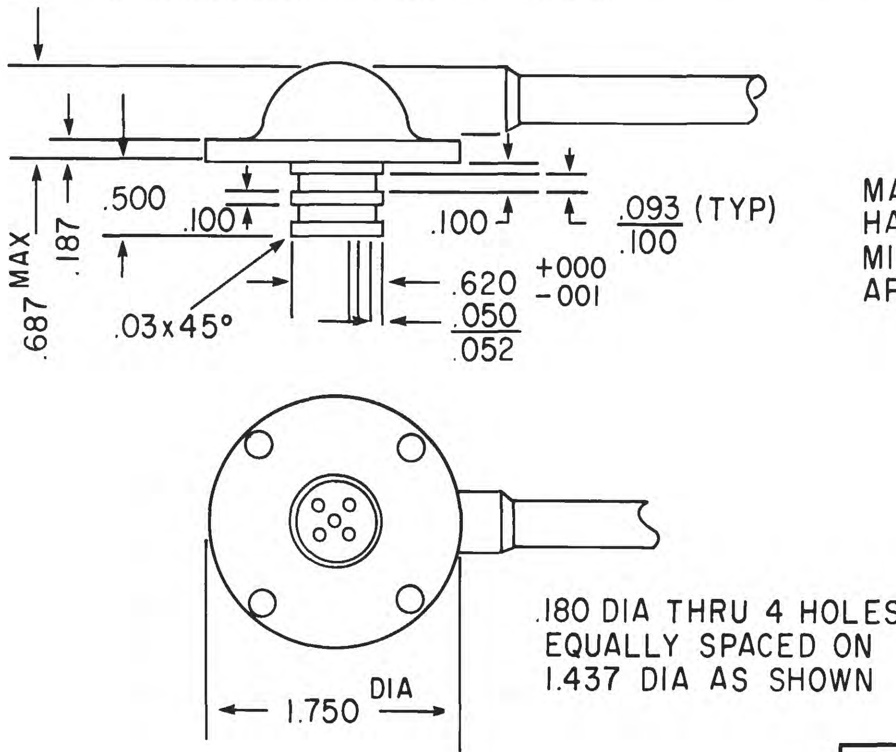

BC·30
WC·38
DC·37
DC·37
XP·35
J·20
J·21
J·22
J·23
J·24
J·25
V·F
FTIC T
PWR
C·V
VECT
DUAL
FTIC E
FTIC N
FTIC R
CLOCK
CASS
HEAD
MOTOR
P17

Figure 3

Figure 4

NOTES:

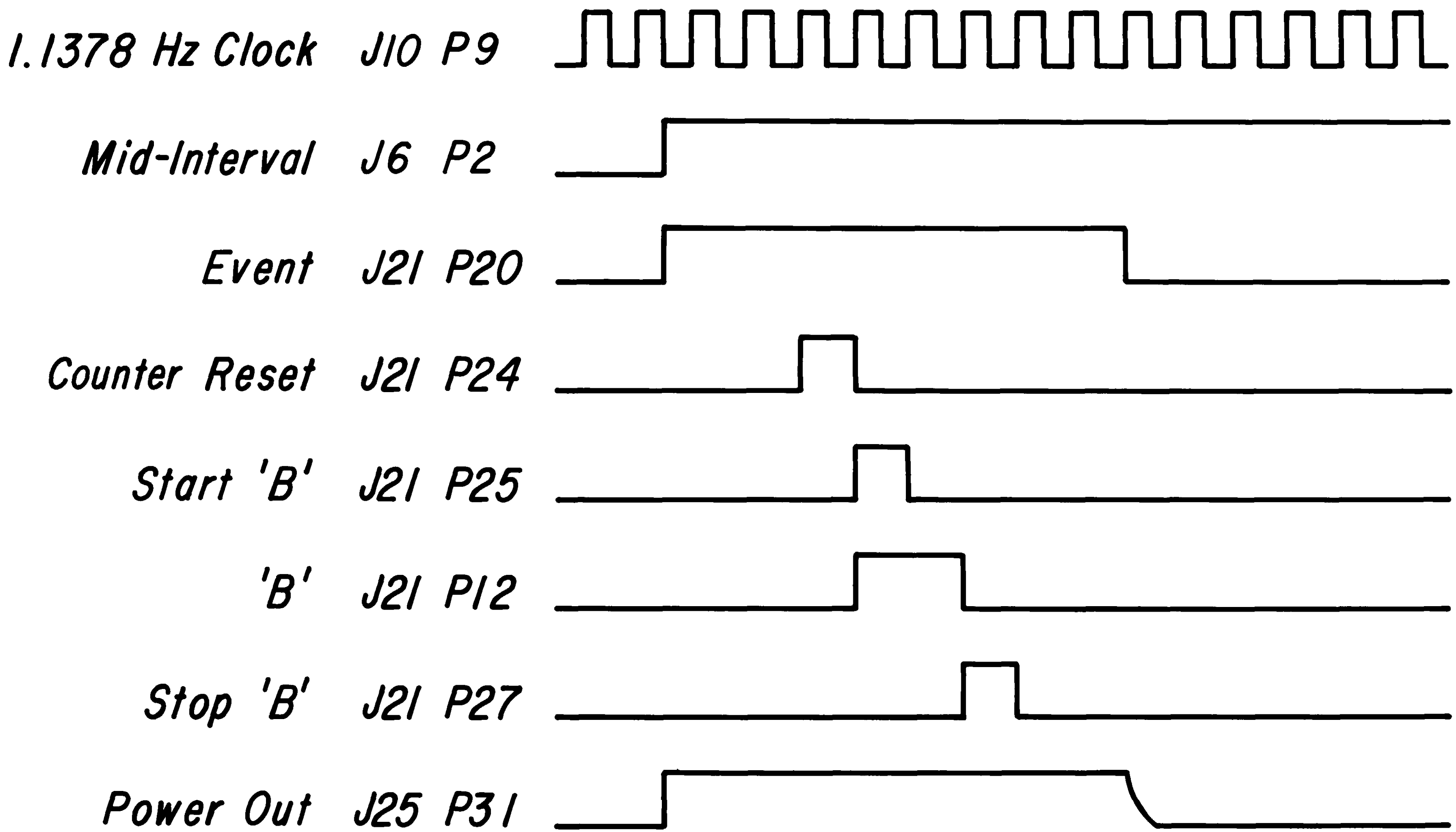
1. INDIVIDUAL CONDUCTORS MUST BE WATER BLOCKED IN THE PENETRATOR.
2. ASSEMBLY MUST BE CAPABLE OF WITHSTANDING SEAWATER PRESSURES OF 10,000 PSI WITHOUT LEAKING.



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

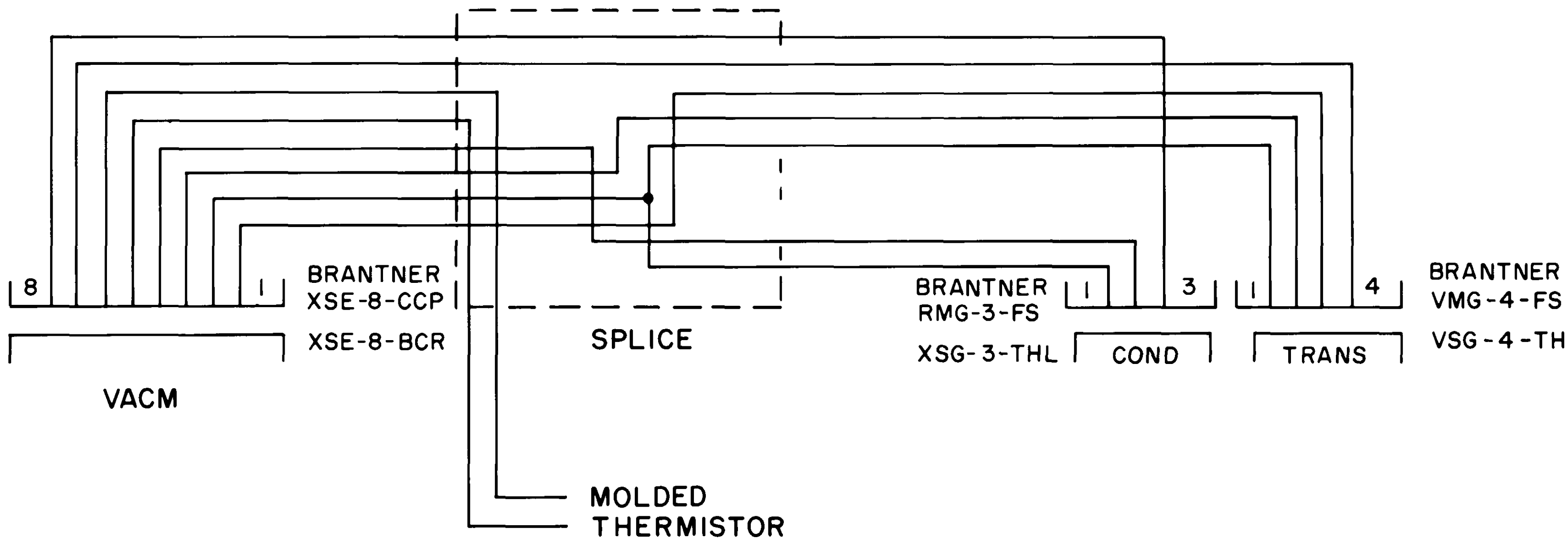
PENETRATOR ASSEMBLY VACM	
DRAWING 9.1	NOV. 22, 1983

Figure 5



TIMING DIAGRAM

Figure 6



SYSTEM CABLE DIAGRAM

Figure 7

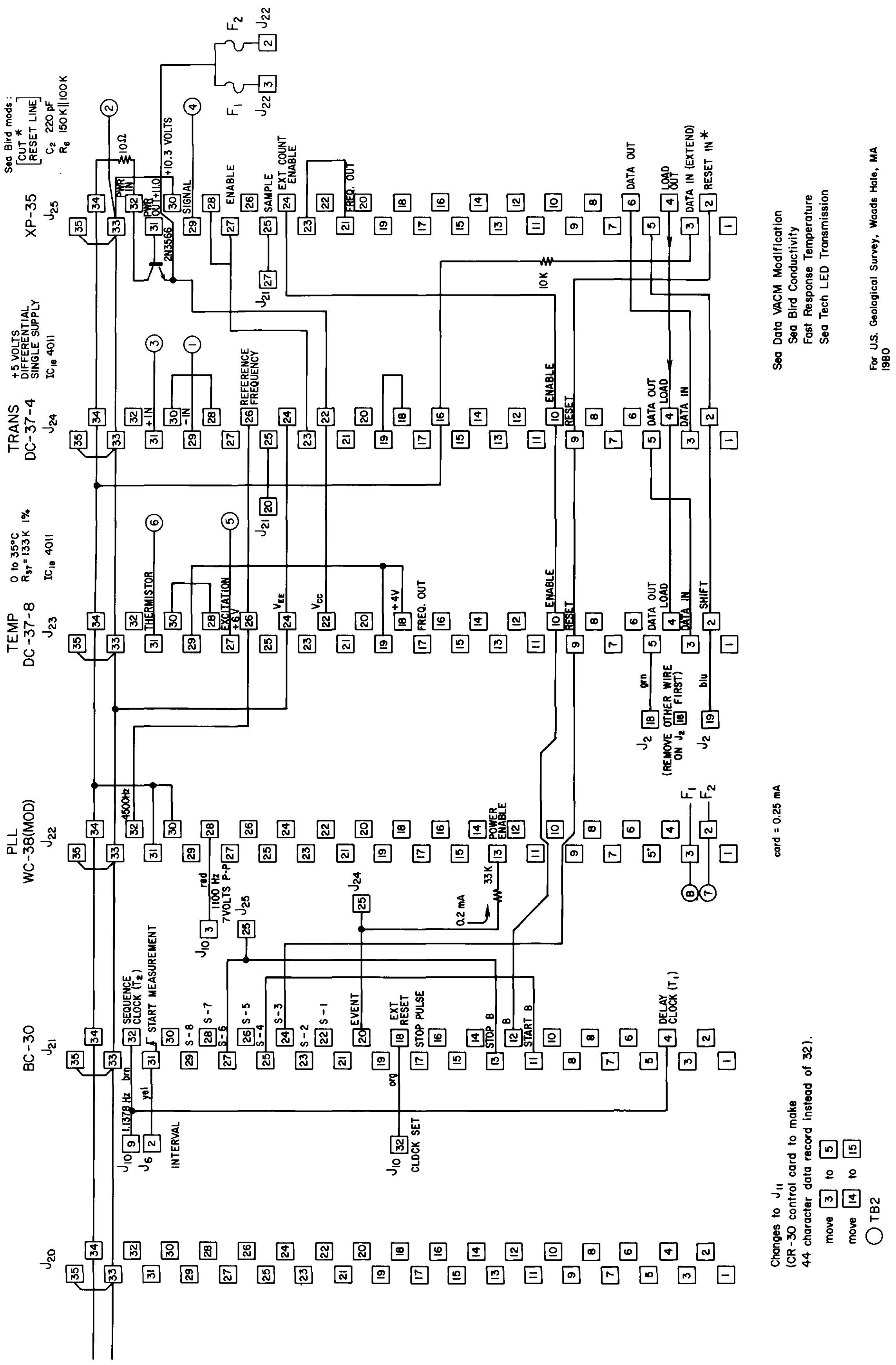
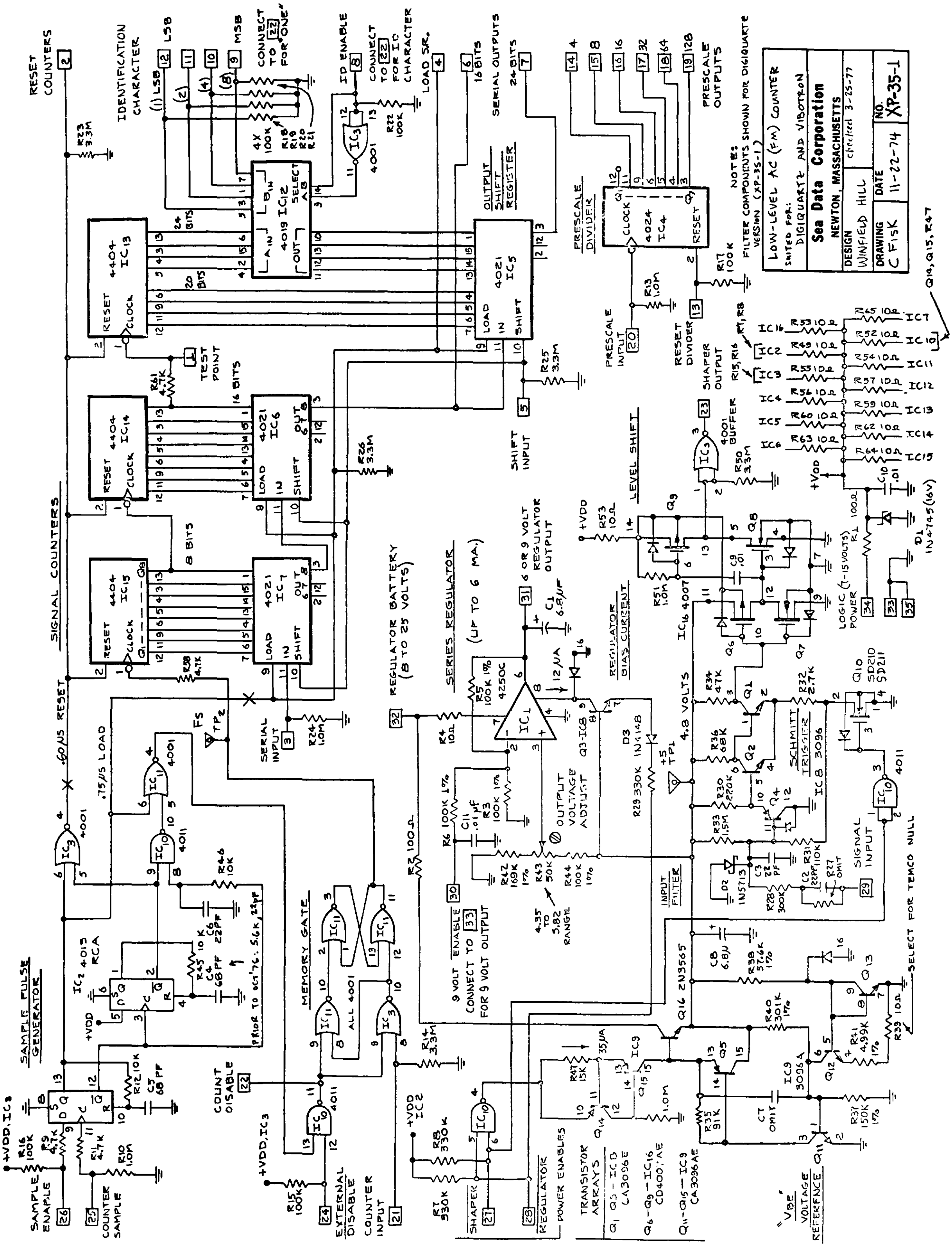

Sea Data VACM Modification
Sea Bird Conductivity
Fast Response Temperature
Sea Tech LED Transmission
For U.S. Geological Survey, Woods Hole, MA
1980
Sea Bird mods :
CUT * RESET LINE
C2 220 pF
R6 150 K || 100 K
XP-35
J25
+5 VOLTS
DIFFERENTIAL
SINGLE SUPPLY
IC18 4011
TRANS
DC-37-4
J24
0 to 35°C
R37 = 133K 1%
IC18 4011
TEMP
DC-37-8
J23
PLL
WC-38(MOD)
J22
BC-30
J21
J20
Changes to J11
(CR-30 control card to make
44 character data record instead of 32).
move 3 to 5
move 14 to 15
TB2
card = 0.25 mA

Figure 8



SIGNAL COUNTERS
SAMPLE PULSE GENERATOR
MEMORY GATE
SERIES REGULATOR
INPUT FILTER
SCHMITT TRIGGER
LEVEL SHIFT
PRESCALE DIVIDER
OUTPUT SHIFT REGISTER
IDENTIFICATION CHARACTER
RESET COUNTERS
SERIAL OUTPUTS
PRESCALE OUTPUTS
REGULATOR BATTERY (8 TO 25 VOLTS)
LOW-LEVEL AC (FM) COUNTER
Sea Data Corporation
NEWTON, MASSACHUSETTS
XP-35-1

Figure 9

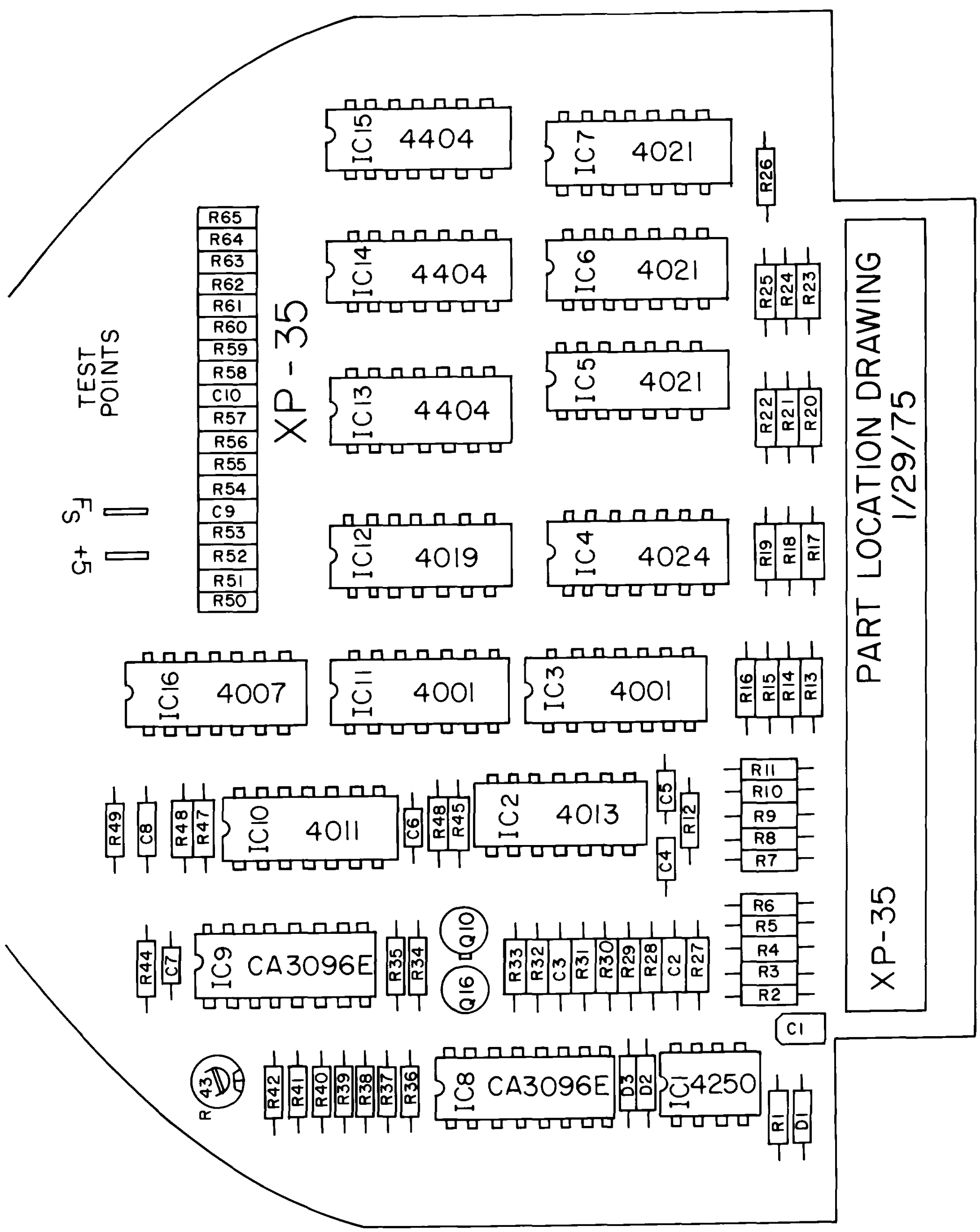

PART LOCATION DRAWING
1/29/75
XP-35
XP - 35
TEST POINTS
F_S
+5
IC15 4404
IC14 4404
IC13 4404
IC12 4019
IC11 4001
IC16 4007
IC10 4011
IC9 CA3096E
IC8 CA3096E
IC7 4021
IC6 4021
IC5 4021
IC4 4024
IC3 4001
IC2 4013
IC1 4250

Figure 10

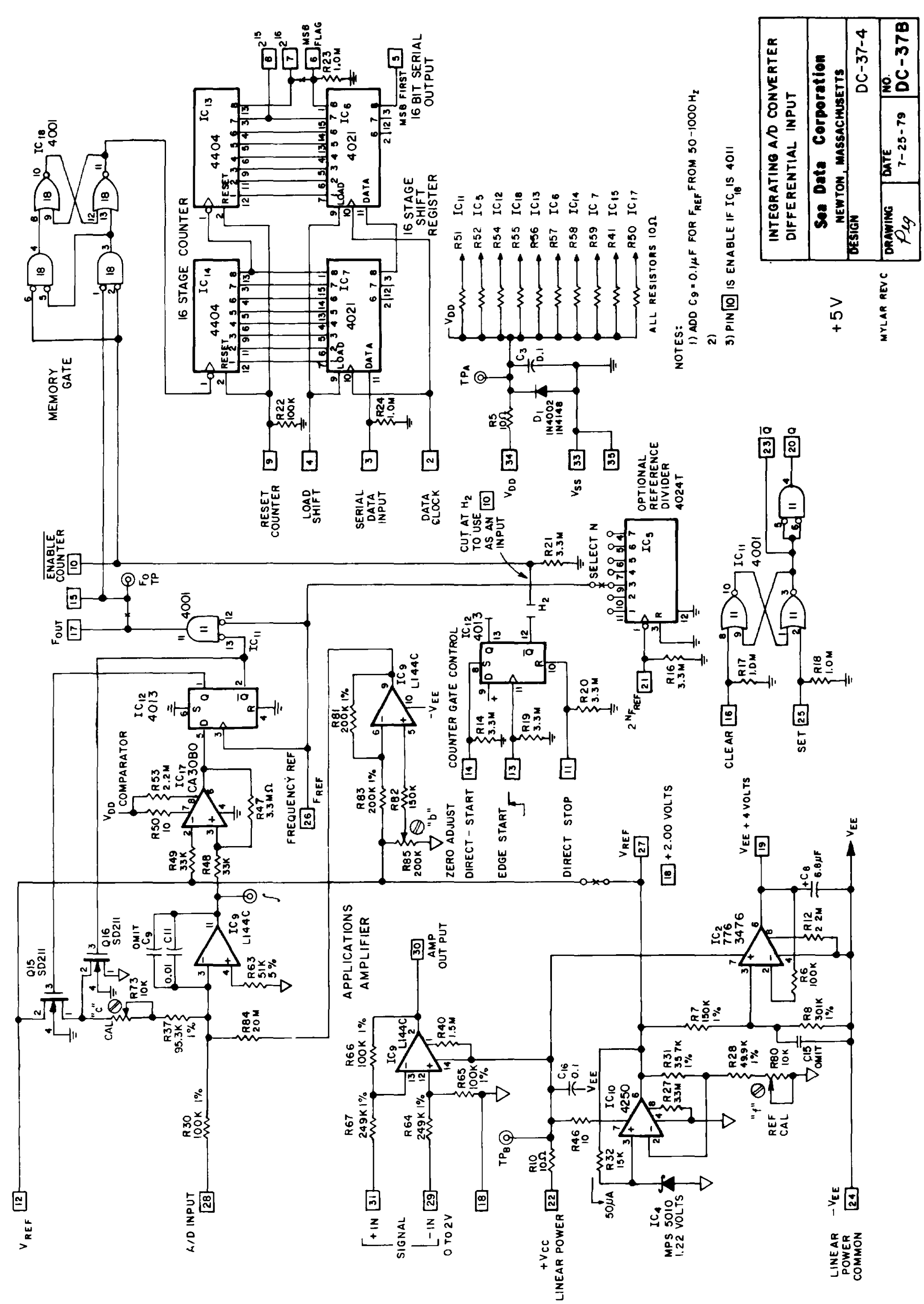
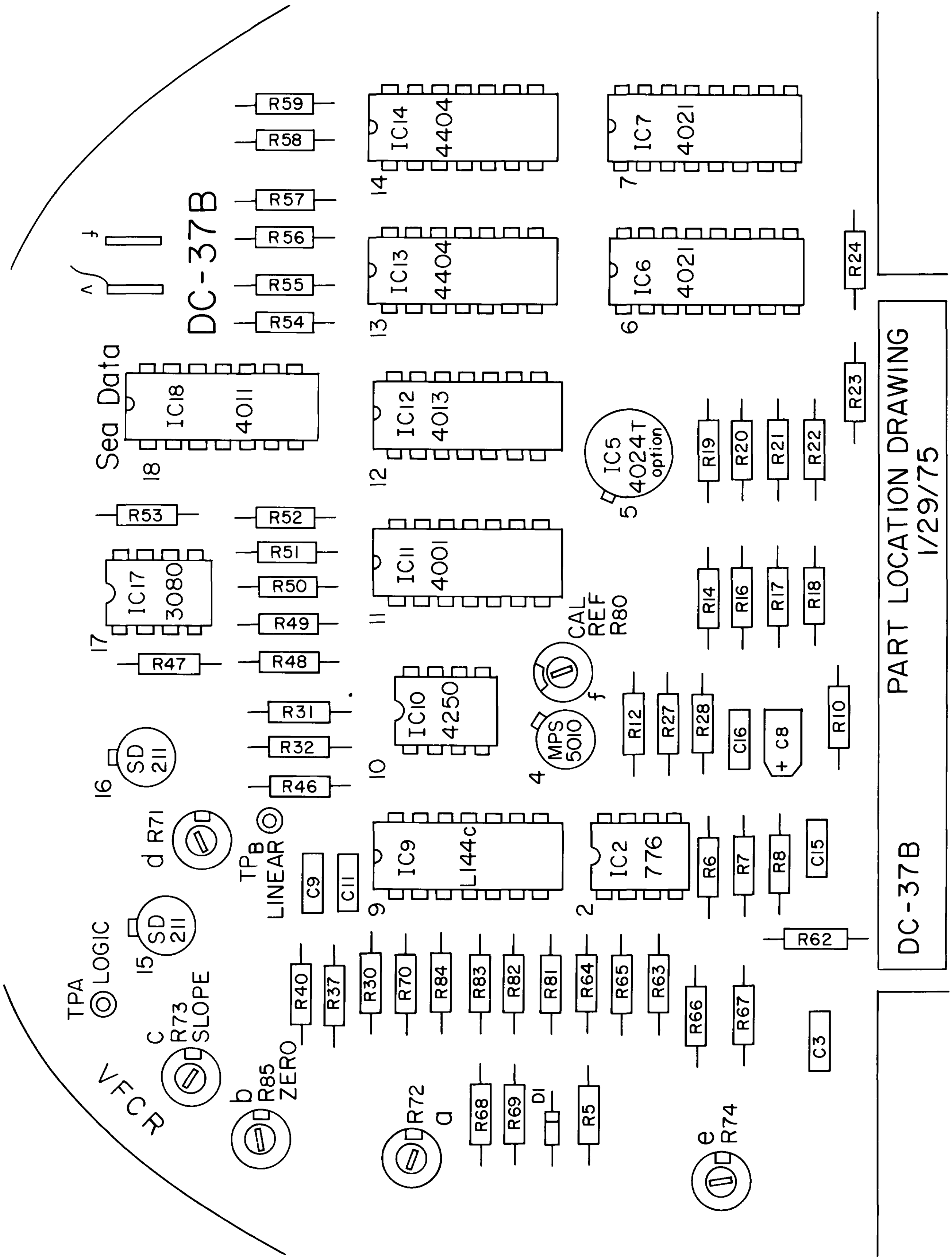
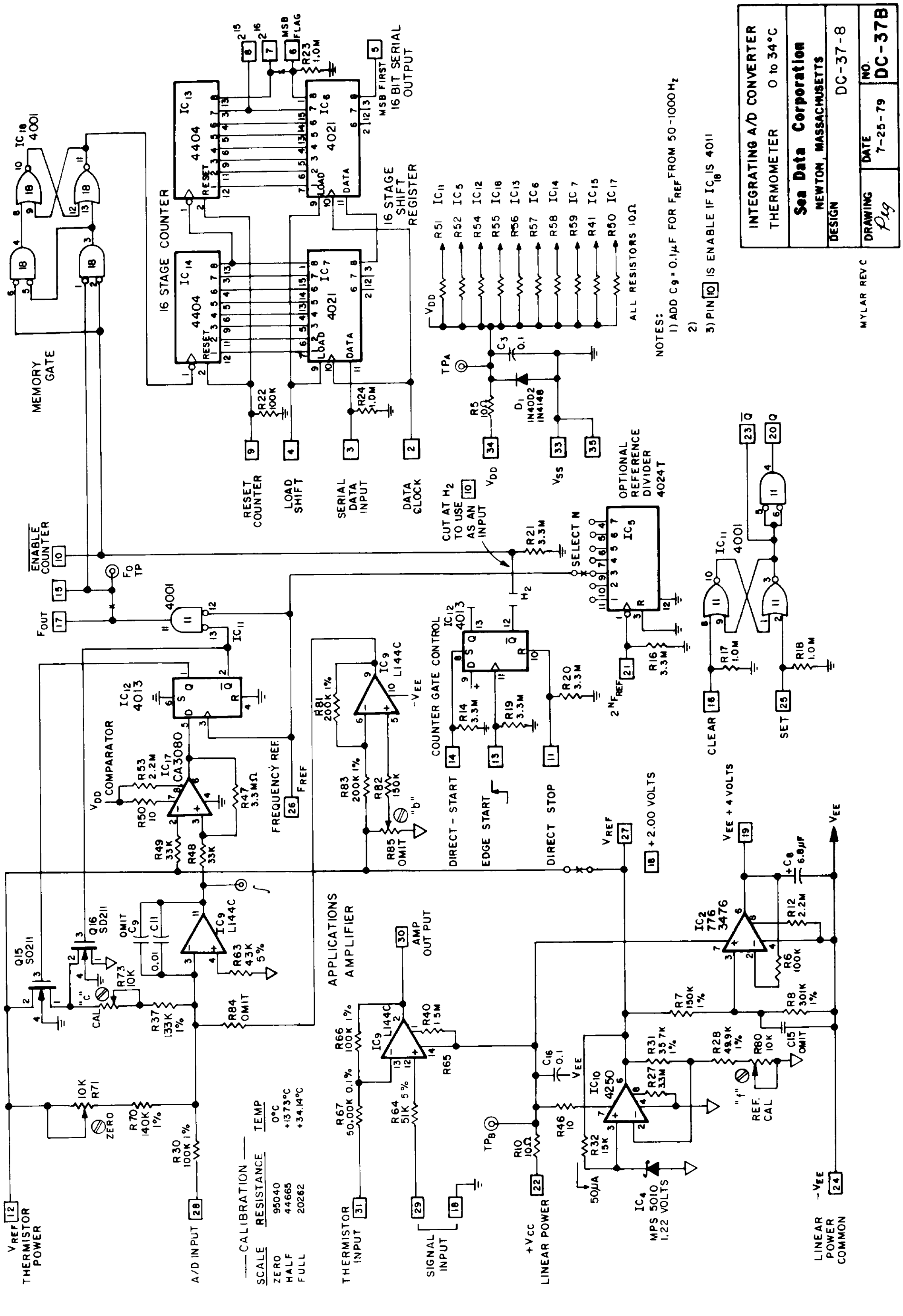

INTEGRATING A/D CONVERTER
DIFFERENTIAL INPUT
Sea Data Corporation
NEWTON, MASSACHUSETTS
DC-37-4
DATE 7-25-79
NO. DC-37B

Figure 11



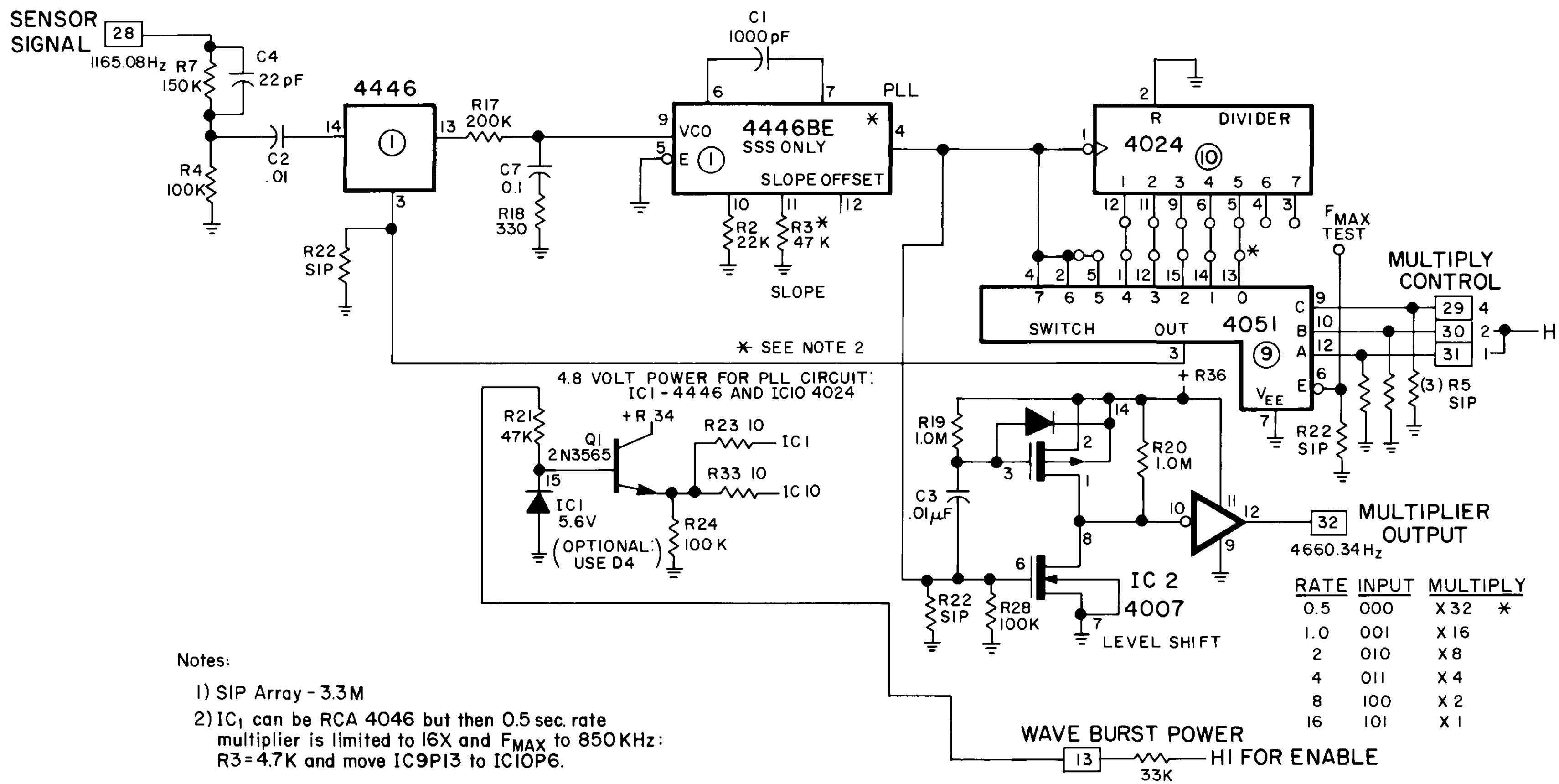
Sea Data
DC-37B
PART LOCATION DRAWING
1/29/75
DC-37B
VFCR
TPA LOGIC
TPB LINEAR
CAL REF R80
c R73 SLOPE
b R85 ZERO
a R72
d R71
e R74
IC18 4011
IC17 3080
IC14 4404
IC13 4404
IC12 4013
IC11 4001
IC10 4250
IC9 L144c
IC7 4021
IC6 4021
IC5 4024T option
IC2 776
SD 211
MPS 5010

Figure 12



INTEGRATING A/D CONVERTER
THERMOMETER 0 to 34°C
Sea Data Corporation
NEWTON, MASSACHUSETTS
DESIGN
DC-37-8
DRAWING
DATE 7-25-79
NO. DC-37B
MYLAR REV C
NOTES:
1) ADD Cg = 0.1µF FOR FREF FROM 50-1000Hz
2)
3) PIN 10 IS ENABLE IF IC18 IS 4011
ALL RESISTORS 10Ω
CALIBRATION
SCALE RESISTANCE TEMP
ZERO 95040 0°C
HALF 44665 +17.3°C
FULL 20262 +34.14°C
16 STAGE COUNTER
16 STAGE SHIFT REGISTER
16 BIT SERIAL OUTPUT
MSB FIRST
MEMORY GATE
ENABLE COUNTER
RESET COUNTER
LOAD SHIFT
SERIAL DATA INPUT
DATA CLOCK
COMPARATOR
FREQUENCY REF
COUNTER GATE CONTROL
DIRECT - START
EDGE START
DIRECT STOP
OPTIONAL REFERENCE DIVIDER 4024T
SELECT N
CLEAR
SET
APPLICATIONS AMPLIFIER
AMP OUT PUT
THERMISTOR INPUT
SIGNAL INPUT
A/D INPUT
THERMISTOR POWER
LINEAR POWER
LINEAR POWER COMMON
REF. CAL
ZERO
CAL

Figure 13



Notes:

1) SIP Array - 3.3M

2) IC_1 can be RCA 4046 but then 0.5 sec. rate multiplier is limited to 16X and F_{MAX} to 850 KHz: R3 = 4.7K and move IC9P13 to IC10P6.

WAVE CONTROL
PLL
NO. WC-38

Figure 14

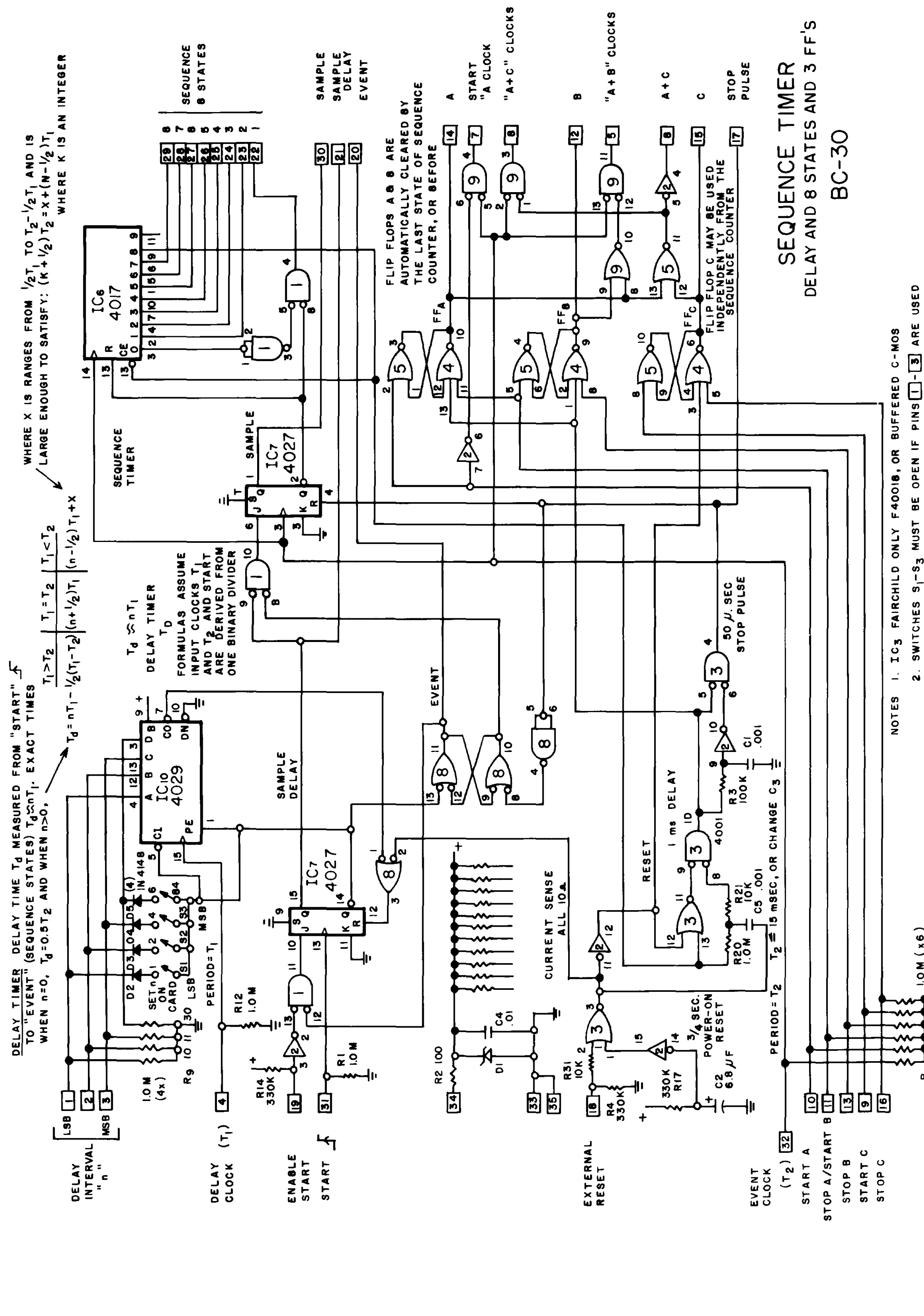

SEQUENCE TIMER
DELAY AND 8 STATES AND 3 FF'S
BC-30
NOTES 1. IC3 FAIRCHILD ONLY F4001B, OR BUFFERED C-MOS
2. SWITCHES S1-S3 MUST BE OPEN IF PINS 1-3 ARE USED

Figure 15

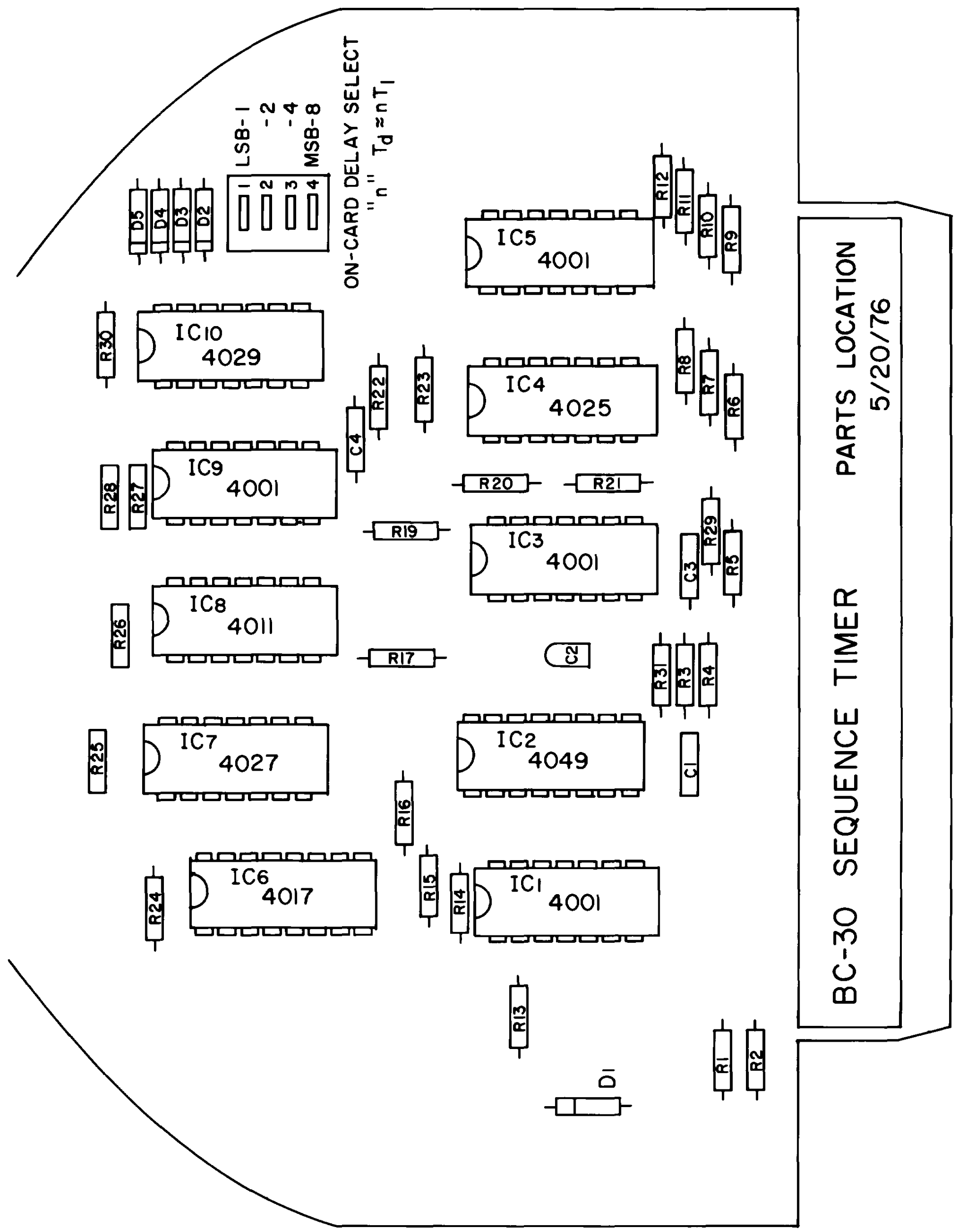

BC-30 SEQUENCE TIMER
PARTS LOCATION
5/20/76
ON-CARD DELAY SELECT
"n" $T_d = nT_1$
LSB-1
-2
-4
MSB-8
IC1 4001
IC2 4049
IC3 4001
IC4 4025
IC5 4001
IC6 4017
IC7 4027
IC8 4011
IC9 4001
IC10 4029

Figure 16