A CONTINUOUS WATER-SAMPLING AND MULTIPARAMETER-MEASUREMENT SYSTEM FOR ESTUARIES : AN IMPROVED SYSTEM FOR SMALL VESSELS

By Lee A. Dedini and Laurence E. Schemel

U. S. GEOLOGICAL SURVEY

Open-File Report 80-1293

Prepared as part of continuing

San Francisco Bay estuarine study

October 1980

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, Secretary

GEOLOGICAL SURVEY

H. William Menard, Director

OPEN-FILE REPORT

For additional information write to:

Regional Hydrologist
Water Resources Division
U. S. Geological Survey
345 Middlefield Road
Menlo Park, CA 94025

CONTENTS

	Page
List of Tables	4
List of Figures	5
Abstract	6
Introduction	7
Water Pumps	8
Digital-Display Panels and Instruments	9
Analog Strip-Chart Recorders	13
References	14
Tables	15
Figures	24

List of Tables

Page

1. Manufacturers of instruments and equipment 15

2. Instrument signal level characteristics 16

3. Identification and sources of major components of display panels 17

4. Identification and sources of major components of recorders 18

5. Panel 1: front panel connections 19

6. Panel 1: rear panel connections 20

7. Panel 2: front panel connections 21

8. Panel 2: rear panel connections 22

9. HP 25C program for OmV pH calculation 23

List of Figures

Page

1. Water pumping system on R.V. Estero 24
2. Block diagram of continuous measurement instruments and data aquisition system 25
3. Front view layout: Panel 1 26
4. Top view layout:. Panel 1 27
5. Top view: Panel 1 28
6. Circuitboard CB1 (Panel 1)or (Panel 2) schematic diagram . 29
7. Circuitboard CB2 (Panel 1) schematic diagram 30
8. Circuitboard CB2 (Panel 1) schematic diagram 31
9. Circuitboard CB3 (Panel 1) schematic diagram 32
10. Digital panel meter and panel switch connections:Panel 1 . 33
11. _In situ_ temperature/depth probe and bow-intake temperature schematic diagram 34
12. Front view layout: Panel 2 35
13. Top view layout: Panel 2 36
14. Top view: Panel 2 37
15. Circuitboard CB2 (Panel 2) schematic diagram 38
16. Circuitboard CB3(Panel 2) schematic diagram 39
17. Circuitboard CB4 (Panel 2) schematic diagram 40
18. Digital panel meter and panel switch connections:Panel 2 . 41
19. Infrared analyzer response curves at various gain settings 42
20. Block diagram of recorders 43
21. Front view: Recorders 44
22. Front layout of control section: Recorders 45
23. Side view: Recorders 46
24. Side layout of control section: Recorders 47
25. Attenuation and amplifier schematic diagrams: Recorders . . 48
26. Wiring diagram of controls to recorder connectors 49

ABSTRACT

Salinity, temperature, turbidity, chlorophyll a fluorescence, pCO_2, pH, oxygen saturation, and concentrations of five dissolved nutrient substances (nitrate, nitrite, ammonia, dissolved silica, and orthophosphate) can be continuously measured by instruments in an integrated system. The system is compact and has been installed on a 30-foot long shallow-draft vessel capable of navigating in the shallow reaches of San Francisco Bay estuary. The system was assembled from commercially available instruments, equipment, and components, and from specialized items which were designed and fabricated by the authors. Near-surface water is pumped continuously while underway, producing data profiles from one depth. Data are read from digital meters and recorded on analog strip-charts and magnetic tape.

Introduction

This report describes the continuous water-sampling and water-analysis system which has been installed on the 30-foot-long U. S. Geological Survey research vessel Estero. This system was designed primarily for mapping water-quality parameters in the shallow regions of San Francisco Bay estuary. Many features are similar or identical to the system described by Schemel and Dedini (1979), but this newer system incorporates many electronic and design improvements and is more compact, allowing it to be installed on small vessels. In addition, we have been able to reduce cost, particularly by purchasing OEM (original equipment manufacturer) components when possible.

We have limited the scope of this report primarily to a description of the digital-display panels and the analog strip-chart recorders because these are the assemblies which comtain most of the important changes. However, we do note some other changes in equipment and instrumentation. Analytical methods, calibration procedures, and other detailed information can be found in our previous reports (Schemel and Dedini 1979, 1980) and in the appropriate operation manuals (Table 1). Details of the micro-processor-based data logger and magnetic-tape recording system and the digital fathometer are described in a following report by K. Leap (U.S.G.S., Menlo Park, CA).

WATER PUMPS

Near-surface water from a depth of about 0.5m is continuously pumped with a flexible-impeller centrifugal pump (Fig. 1). A section of aluminum pipe (1¼-in.ID) penetrates the hull and extends to above the water line; water is drawn from a section of PVC pipe(1-in.ID) inserted through the aluminum pipe. The PVC pipe can be adjusted so that air or bubbles are not taken in and, as a safety factor, the pipe will break without damaging the hull if the vessel hits an object. The intake of the pipe is cut at an angle of about 30 degrees (Fig. 1) to minimize cavitation and degassing of the water. The pump is coupled to the PVC pipe with reinforced flexible PVC tubing and is located about 0.5m above the water line. The pump discharges about 50L $min.^{-1}$; water which is not used for the instruments is discharged overboard in order to minimize the flushing time of the system (approx. 5-10 sec.).

Circuits have been provided in the digital-display panels so that an *in situ* pumping system with temperature and depth sensors can be used. We refer the reader to Schemel and Dedini (1979) for details concerning the construction and operation of this system.

Digital-Display Panels and Instruments

The pumped water flows through instruments with flow-sample cells or sensors are directly immersed in the water stream (Fig. 2). The following discussion will exclude the five-channel nutrient analyzer (except when specific references are made) because it is practically independent of the digital-display panels and has separate strip-chart recorders. Continuous-measurement signals (Table 2) are displayed on digital meters and are recorded on two four-channel strip-chart recorders, except for the *in situ* depth measurement (when used). Amplified or attenuated signals buffered by amplifiers with 1.5 sec. time constants (RC) are read by the data logger at switch-selectable multiples of 5 sec. (usually 30 sec.) and recorded on magnetic tape.

The digital-display panels contain circuitry for sensors and signal-processing circuits necessary for data recording, including signals from the five-channel nutrient analyzer. Drawings and electrical schematic diagrams for the digital-display panels are Figures 3 through 18. Each panel is a standard width (19 in.) rack chassis (Table 3). Digital meters, instrment and sensor connectors, and power-and voltage-source switches are mounted on the front panels. Other signal connections are made at the rear panel. Circuit components are hand-wired and all connections are soldered when possible. Most circuit components are mounted on prototype circuit boards.

Modular regulated supplies power all panel circuitry (±15VDC) and the digital panel meters (+5VDC). Precise regulated DC voltages are generated on the circuitboard located by the modular supplies (for example, (Fig.4)). These voltages are required for sensors and calibrations. For example, each panel has "Cal" switches which select full-scale voltages for calibrating the digital meters and strip-chart recorders and for checking the operation of the data logger and magnetic tape recorder.

Both panels provide zero-offset circuits which enable a limited range of a parameter to be recorded across the full width of the strip-chart (50mm). For example, temperature changes in the range of 10-20^{o}C can be recorded with a resolution of $\pm$0.1^{o}C. In this case an offset voltage equivalent to the signal level at 10^{o}C is applied to the low side of the recorder differential input and the recorder attenuation is set for a full scale range of 10^{o}C. The rotary switches select the appropriate voltage offset; they are calibrated in the parameter units or in percent of full range increments.

The digital-display panels accept and condition signals from instruments and sensors. We have changed some of our previous designs to allow us to use newer or different instruments. A Md.10 fluorometer with a nephelometry flow cell,or a Md.40 nephelometer,can be connected to the turbidity channel; a switch on the circuit board selects the appropriate circuitry. The circuitry design for the pH meter optical isolation and digital-to-analog converter has been modified to accept TTL-level signals from a Md. 701A pH meter. An additional (ground-isolated) +5VDC supply is necessary to power the digital logic. Panel circuitry for the pCO_2 measurement system has been modified to accept signals from a Md. 864 non-dispersive infrared analyzer; response curves are shown in Fig. 19.

All temperature measurements are made with linearized thermistor sensors. These sensors are connected to circuitry in the panels except for the intake-temperature and _in situ_-temperature measurements. In these cases the circuitry is contained in water-proof enclosures and voltages are transmitted to panel 1. Modifications of the in situ-temperature and depth circuits are shown on Fig. 11. A zero-depth adjustment is provided on panel 1.

The dissolved oxygen sensor is a polaragraphic electrode. The probe is polarized (-0.84VDC) and the resulting current is proportional to the partial pressure of oxygen in the sample. A thermistor in the probe varies the amplifier gain to compensate for variations in the membrane diffusivity with temperature. However, this compensation is inadequate above 22°C, where most air calibrations are made. We are currently evaluating the merits of making uncorrected electrode-current measurements and correcting for the measurement temperature in our data-reduction procedure. Either of two fixed resistors equivalent to the temperature compensation resistances at 25°C and 12°C can be selected instead of the thermistor. These resistors will give adequate voltage gain at high or low temperatures.

Our changes in the pH data collection and correction routines are similar in concept to what we envision for the dissolved oxygen system. The electrode (cell) potentials and corresponding sample temperatures are collected as the raw data; our previous data were collected in pH units. Periodic calibrations with 7.413 (@25°C) buffer (Beckman #3008) are made at temperatures near the sample temperatures. The following calculations are based on the assumption that the electrode response is nearly theoretical. We check the response periodically with two buffers to assure that large deviations from the theoretical response (slope: mV/pH) do not occur.

Within the temperature range of our measurements (0-25°C) the following expressions can be used:

Theoretical Slope (mV/pH) = 54.1960 + 0.1984 T   eq. 1 [1/]

Buffer pH (7.413 @25 C) = $7.531 - 6.65x10^{-3}T + 7.64x10^{-5}T^2$,   eq. 2 [2/]

where T is the temperature in centigrade degrees.

The pH meter reading in mV is divided by the theoretical slope to give a Δ pH. The pH value corresponding to the OmV reading is computed from the pH meter reading in buffer and the theoretical slope: [3/]

$$\text{OmV pH} = \text{buffer pH} + \frac{\text{(mV reading in buffer)}}{\text{(theoretical slope)}} \qquad \text{eq. 3}$$

Note that mV reading will be negative in the 7.41 buffer. Linear drift is assumed between calibrations. The sample pH is computed from the OmV pH and the Δ pH:

$$\text{Sample pH} = \text{OmV pH} - \Delta\text{ pH} \qquad \text{eq. 4}$$

Note that Δ pH values will be negative because most samples will be more alkaline than the OmV pH value.

Values are reported to the nearest 0.01 pH unit. We expect that measurements made by this procedure are accurate at the $\pm$ 0.05 pH level and not suitable for some applications.

1/ Eq. 1 is our fit to the values tabulated in Bates, R.G., 1973, Determination of pH, John Wiley & Sons, New York, 479 p.

2/ Eq. 2 is our fit to the data supplied by the manufacturer for Buffer # 3008 .

3/ This calculation can be easily done on a calculator; a program for the HP 25C (Hewlett-Packard, Palo Alto, CA.) is shown in Table 9.

Analog Strip-Chart Recorders

Drawings and electrical schematics diagrams for the four-channel analog strip-chart recorders are shown in Figures 20 through 26. Each recorder uses an OEM recorder unit (Table 4). The encased recorders (Fig. 21) fit on angle brackets inside standard-width (19 in.) electronic racks. The dimensions of the recorders are 17 1/2 in. wide, 9 1/2 in. high, and 8 1/2 in. deep. The OEM recorder units comprise: 1) the chassis, 2) four galvanometers, 3) the paper-drive system, 4) four thermal-writing styluses, 5) power- and signal-input connections, 6) and power supplies (Fig. 20). The chassis is mounted on 1/8-in. thick aluminum sheet and angle material (Fig. 23), and aluminum panels (1/16-in.-thickness) enclose the control-section components (Fig. 23 does not show the top and side panels). The front panel fits flush with the chart-paper table. Operating controls mounted on the front panels (Fig. 22) include those for zero pen positioning, gain adjustment, pen-heat adjustment, a five-step attenuator for each channel, power, chart-speed selection, and event marker.

Signal-input connections are made at the rear of the control section (Fig. 24). Each channel has a differential-input circuit (Fig. 25) which is mounted on the prototype circuitboard. The single-ended output of each differential-input circuit is applied to a preamplifier circuit (Table 4), which increases the sensitivity of the recorders from 10mV/mm to 1mV/mm.

References

Schemel, L. E. and Dedini, L. A., 1979, A Continuous water-sampling and multiparameter-measurement system for estuaries: U. S. Geological Survey Open-file Report 79-273, 92p.

Schemel, L. E. and Dedini, L. A., 1980, Continuous water-sampling and water analysis in estuaries in Proceedings of Fifth STD/Ocean Systems Conference (in press).

Table 1. Manufacturers of Instruments and Equipment[1/]

Item	Model	Manufacturer
Bow Sampling Centrifugal Pump	777	Jabsco Products, Costa Mesa, California
pH Meter	701A	Orion Research Inc., Cambridge, Massachusetts
pH Combination Electrode	476050	Corning Instruments, Medfield, Massachusetts
Four Channel Analog Recorders, OEM	W402XL	Astro-Med Div., Atlon-Tol Ind., West Warwick, RI
Fluorometers (2)	10-000R	Turner Designs, Palo Alto, California
Nephelometer (optional)	40	Turner Designs, Palo Alto, California
Salinity-Temperature Meter	350	W. Peterson (Consultant), Palo Alto, California
Thermistor Elements	44018	Yellow Springs Instruments, Yellow Springs, Ohio
Oxygen Probe	5400	Yellow Springs Instruments, Yellow Springs, Ohio
Infrared Analyzer	864-X	Beckman Instruments, Fullerton, California
Depth Transducer	PG103	Gentran Inc., Sunnyvale, California
Tape Recorder	4923	Tektronix, Inc., Beaverton, Oregon
Nutrient analyzer (AutoAnalyzer)	II	Technicon Corp., Terrytown, New York
Digital Fathometer	2700	Datamarine, Pocasset, MA.

[1/] The mention of brand names is for identification purposes and does not constitute endorsement by the U.S. Geological Survey.

Table 2. Instrument Signal Level Characteristics.

Measurement	Range	VDC Signal to[1] Panel Meters and Chart Recorders	VDC Signal[2] to Computer
Salinity	0 to 39.9	0 to 3.999 VDC	Same
Temperature	-5 to 35°C	-0.5 to 3.50 VDC	Same
Depth	0 to 100 m	0 to 1.000 VDC	VDC X 2
Oxygen Saturation	0 to 199%	0 to 1.99 VDC	VDC X 2
pCO_2 (infrared analyzer)	0 to 100%	0 to 1.00 VDC	VDC X 2
pH (meter output)	0 to 199 mV	0 to 1.999 VDC	VDC X 2
Fluorescence (Md. 10)	0 to 100%	0 to 1.00 VDC	VDC X 2
Nephelometer (Md. 40)	0 to 100%	0 to 1.00 VDC	VDC X 2
Fluorometer sensitivity	0 to 1.9 VDC nominal		see below[3]
No Data			5.00 VDC
AutoAnalyzer channels	0 to 100%		0 to 5.00 VDC

[1] All voltages are positive unless designated.

[2] VDC signal is buffered. Buffer amplifier has a filter with an RC time constant of 1.5 seconds.

[3] VDC signals for sensitivity scales: Md. 10 Fluorometers (VDC ±0.05).

min.sens. =0.0	100 X =1.00
3.16 X =0.28	316 X =1.28
10 X =0.47	1000 X =1.47
31.6 X =0.69	3160 X = 1.69

Table 3. Identification and Sources of Major Components of Display Panels.

Component		Manufacturer
Front Panel Connections		
3-pin	MS 3102A-14S-1P	Amphenol Div., Bunker Ramo Oak Brook, IL
3-socket	MS 3102A-14S-1S	
4-socket	MS 3102A-14S-2S	
6-socket	MS 3102A-14S-6S	
24-socket	57-40240	
26-pin	PTO2A-16-26S	Bendix Corp., Southfield, MI
Dual 18-pin	58-2075010	Datel Systems, Inc. Mansfield, MA
Circuit Boards		
Prototype boards	No. 12-DE-6	Douglas Electronics, San Leandro, CA
Power Supplies		
Dual supply	±15 VDC 200 ma Md. BPM-15/200	Datel Systems, Inc. Mansfield, MA
Single	+5 VDC 3 AMPS Md. USM-5/3	
Single	+5 VDC 1 AMP MD.JE200	Jameco Electronics, Belmont, CA
Digital Panel Meters		
0-19.999V	Md. DM-4100L	Datel Systems, Inc. Mansfield, MA
Rotary Switches		
1 pol.-12pos. non-shorting	Md. PSA-201	Centralab, Milwaukee, WI
1 pol.-12pos. shorting	Md. PSA-200	
Rack Chassis		
19" X 7" X 13" aluminum Md. No. HC-14104		Bud Radio, Inc. Willoughby, OH
Integrated Circuit		
Digital to Analog converter 12 Bit Md. DAC 80-CCD		Burr-Brown Tucson, AZ

Table 4. Identification and Sources of Major Components of Recorders.

Component	Manufacturer
OEM Strip Chart Recorder	Astro-Med Div., Atlon-Tol Ind. West Warwick, RI
Four Channel MD. W402 XL	
Rear Panel Connectors	
3 pin Type D3M	Switchcraft, Chicago, IL
3 pin MS 3102A-14S-1P	Amphenol Div. Bunker Ramo Oak Brook, IL
Rotory Switches	
2 pol- 6 pos	Grayhill, Inc., La Grange, IL
1 pol- 11 pos	Centralab, Milwaukee, WI
Potentiometers	
5K ohm No. 3852B-202-502A 10K ohm No.3852B-202-103A	Bourns, Inc., Trimpot Div. Riverside, CA
Rheostat	
1 ohm 12½ W No. 0101	Ohmite Co., Skokie, IL
Circuit Boards	
Prototype boards No. 12-DE-6	Douglas Electronics, Inc. San Leandro, CA
Preamplifier Md. A-10 1 Mv/mm	Astro-Med Div., Atlon-Tol Ind. West Warwick, RI

Table 5. Panel 1, Front Panel Connections.

Connector	Function	Pin	Connection	Designation
J-6	Salinometer input	A	COM	common
		B	S-4	salinity signal
		C	S-4	temperature signal
J-7	Bow temperature sensor	A	±15	+15 V
		B	COM	common
		C	-15	-15 V
		D	S-6	Temperature signal
		E	J-12-11,23	shield
J-8	*In situ* T/D probe	A	±15	+15 V
		B	COM	common
		C	-15	-15 V
		D	S-6	temperature signal
		E	CB2	depth signal
		F	COM	shield
J-9	Fluorometer input	A	CB2	signal
		B	"	analog range signal
		C	"	TTL range multiplier
		D	"	digital logic common
		E	"	+5VDC logic power
J-10	Nephelometer input for Model 10 or Model 40	A	CB2	same as J-9 for Md. 10
		B	"	
		C	"	
		D	"	
		E	"	
		F	COM	common
				(Md. 40 uses only pins A and F)

Note: Underscored connections are at regulated voltage supply.

Table 6. Panel 1, Rear Panel Connections.

Connector	Function	Pin	Connection	Designation
J-11	Computer output	1,13	COM	common
		2,14	CB2	salinity signal
		3,15	"	temperature signal
		4,16	"	depth signal X 2
		5,17	"	fluorometer signal X 2
		6,18	"	fluorometer scale
		7,19	"	nephelometer signal X 2
		8,20	"	nephelometer scale
		9,21	"	+3.5V reference signal
		10,22	CB2	No data +5.0 VDC
		12,24	COM	shield
J-12	Recorder output	1,13	S-5	salinity signal
		2,14	CB3	Salinity zero offset
		3,15	CB2	depth signal
		4,16	COM	common
		5,17	CB2	fluorometer signal
		6,18	COM	common
		7,19	CB2	nephelometer signal
		8,20	COM	common
		9,21	S-7	temperature signal
		10,22	CB3	temperature zero offset
		11,23	J-7-E	temperature shield
P-1	AC Line	A	S-1	high 115 VAC
		B	Power module pin 1	neutral
		C	chassis	earth ground
P-2	Auto-Analyzer inputs	A	CB-3	Channel 1
		B	"	" 2
		C	"	" 3
		D	"	" 4
		E	"	" 5
		F	COM	common
J-13	Auto-Analyzer signals to computer	A	CB3	Channel 1
		B	"	" 2
		C	"	" 3
		D	"	" 4
		E	"	" 5
		F	COM	common

Note: Underscored connections are at regulated voltage supply.

Table 7. Panel 2, Front Panel Connections.

Connector	Function	Pin	Connection	Designation
J-5		A	J-1-A2	Common
	Infrared Analyzer input	B	CB3	Signal
		C		N.C.
J-6	pH meter	A	CB4	MSB 1 80
		B	"	2 40
		C	"	3 20
		D	"	4 10
		E	"	5 8
		F	"	6 4
		G	"	7 2
		H	"	8 1
		J	"	9 .8
		K	"	10 .4
		M	"	11 .2
		N	"	LSB 12 .1
		P	"	100
J-7	Oxygen Probe	A	CB3	-0.84 VDC
		B	CB3	cell input
		C	S- 21 on CB3	internal thermistor
		D	CB3	internal thermistor
		E	J-12- 10,22	shield
J-8	Temperature / pCO_2	A	CB2	thermistor red
		B	CB2	thermistor brown
		C	+3.5	thermistor green
		D	S-2	shield
J-9	Temperature / pH	A	CB2	
		B	CB2	(same as J-8)
		C	+3.5	
		D	S-2	
J-10	Temperature / Oxygen probe	A	CB2	
		B	CB2	(same as J-8)
		C	+3.5	
		D	S-2	

Note: Underscored connections are at regulated voltage supply.

Table 8. Panel 2, Rear Panel Connections.

Connector	Function	Pin	Connection	Designation
J-11	Computer output	1,13	COM	common
		2,14	CB3	pCO_2 signal X 2
		3,15	CB4	pH signal X 2
		4,16	CB3	% Oxygen signal X 2
		5,17	CB2	temperature/pCO_2 signal
		6,18	CB2	temperature/pH signal
		7,19	CB2	temperature/D.O. signal
		12,24	COM	shield
J-12	Recorder output	1,13	S-4	pCO_2 signal
		2,14	CB3	pCO_2 zero offset
		3,15		pH signal
		4,16	CB3	pH zero offset
		5,17	S-6	% Oxygen signal
		6,18	CB3	%Oxygen zero offset
		7,19	S-10	selected temperature signal
		8,20	CB3	temperature zero offset
		9,21	S-2	temperature probe shield
		10,22	J-7-E	oxygen probe shield
P-1	AC Line	A	S-1	high 115 VAC
		B	power module pin 1	neutral
		C	chassis	earth ground

Note: Underscored connections are at regulated voltage supply.

Table 9. HP 25C[1/] Program for OmV pH Calcultion.

Registers

0	Buffer pH @ T C calibration
1	0.1984
2	54.196
3	Computed theoretical slope
4	Entered temperature @ pH calibration
5	7.64×10^{-5}
6	6.65×10^{-3}
7	7.531

Program

Line		Line	
1	Sto 4	14	x
2	RCl 1	15	-
3	x	16	RCl 7
4	RCl 2	17	+
5	+	18	Sto 0
6	Sto 3	19	R/S
7	R/S	20	Enter
8	RCl 4	21	RCl 3
9	x^2	22	÷
10	RCl 5	23	CLS
11	x	24	RCl 0
12	RCl 4	25	+
13	RCl 6	26	GTO 00

Instructions

Key	T C @ pH calibration
Key	R/S
	Record theoretical slope, if needed
Key	R/S
	Record buffer pH @ T C calibration, if needed
Key	Calibration data as - (mV reading)
	i.e., -25.OmV will be keyed as 25.0
Key	R/S
	Record OmV pH value

1/ The mention of brand names if for identification purposes and does not constitute endorsement by the U.S. Geological Survey.

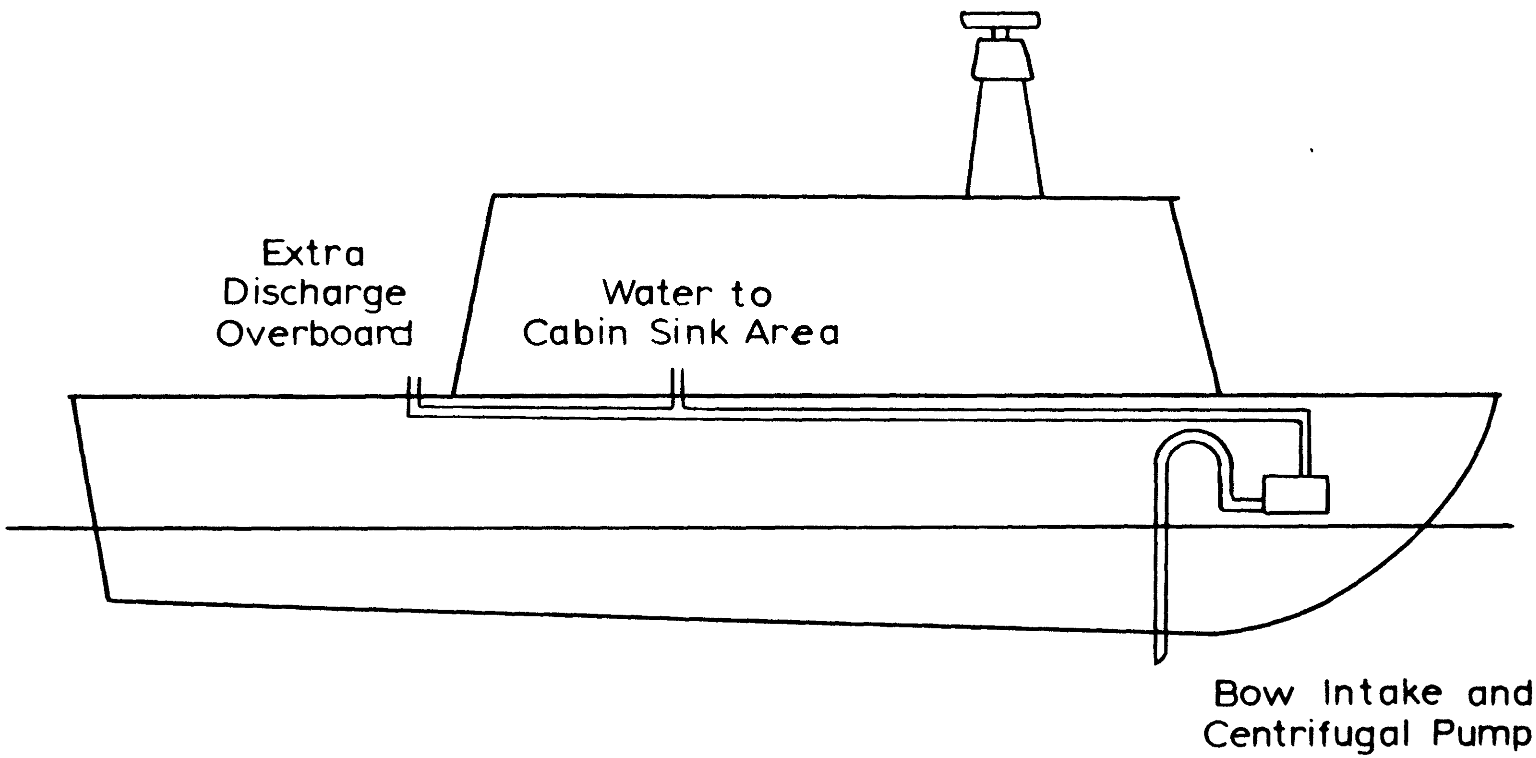


Figure 1. Water pumping system on R.V. Estero.

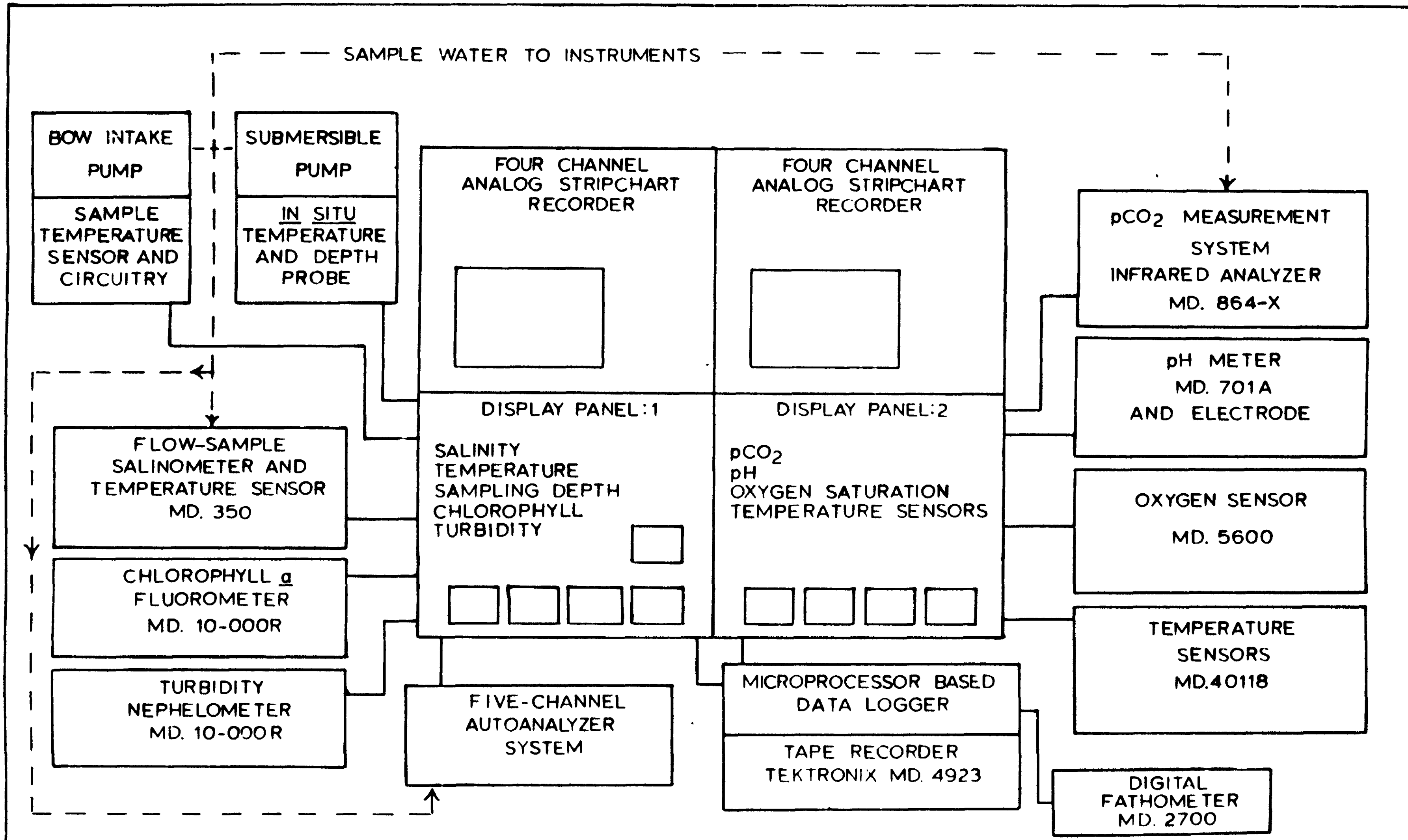


Figure 2. Block diagram of continuous measurement instruments and data acquisition system.

DRAWN BY L.D.
DATE JUNE '80

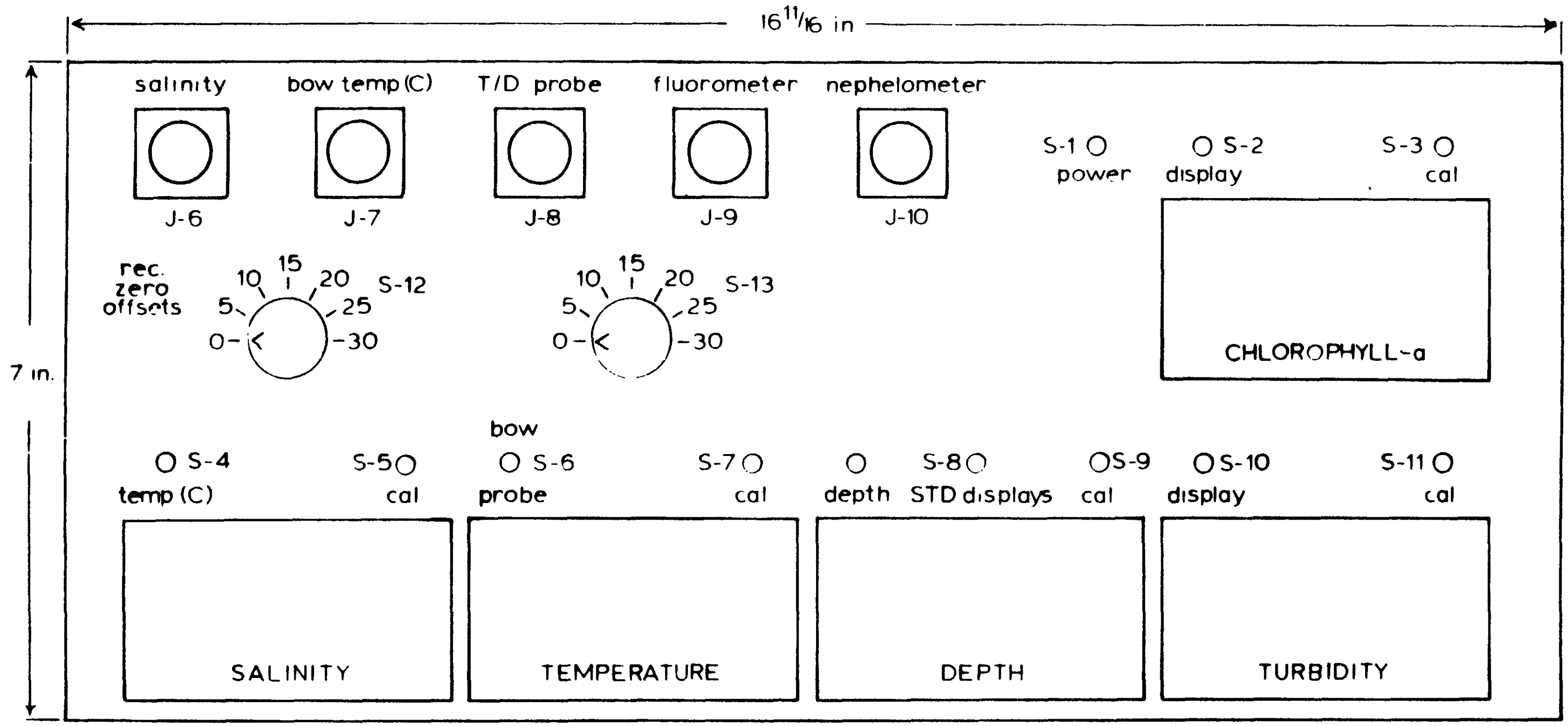


Figure 3. Front view layout: Panel 1.

DRAWN BY L D
DATE JUNE '80

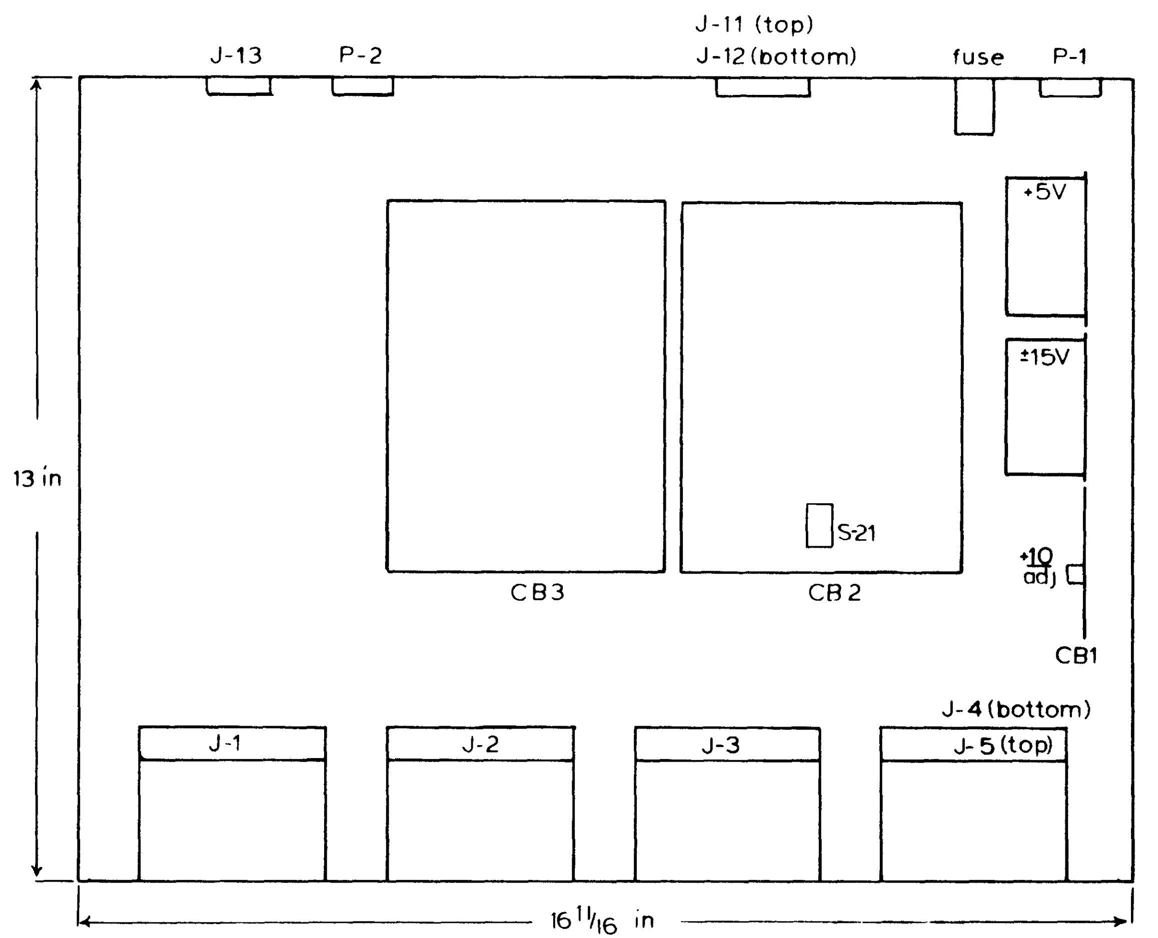


Figure 4. Top view layout: Panel 1.

DRAWN BY L D.
DATE JUNE '80

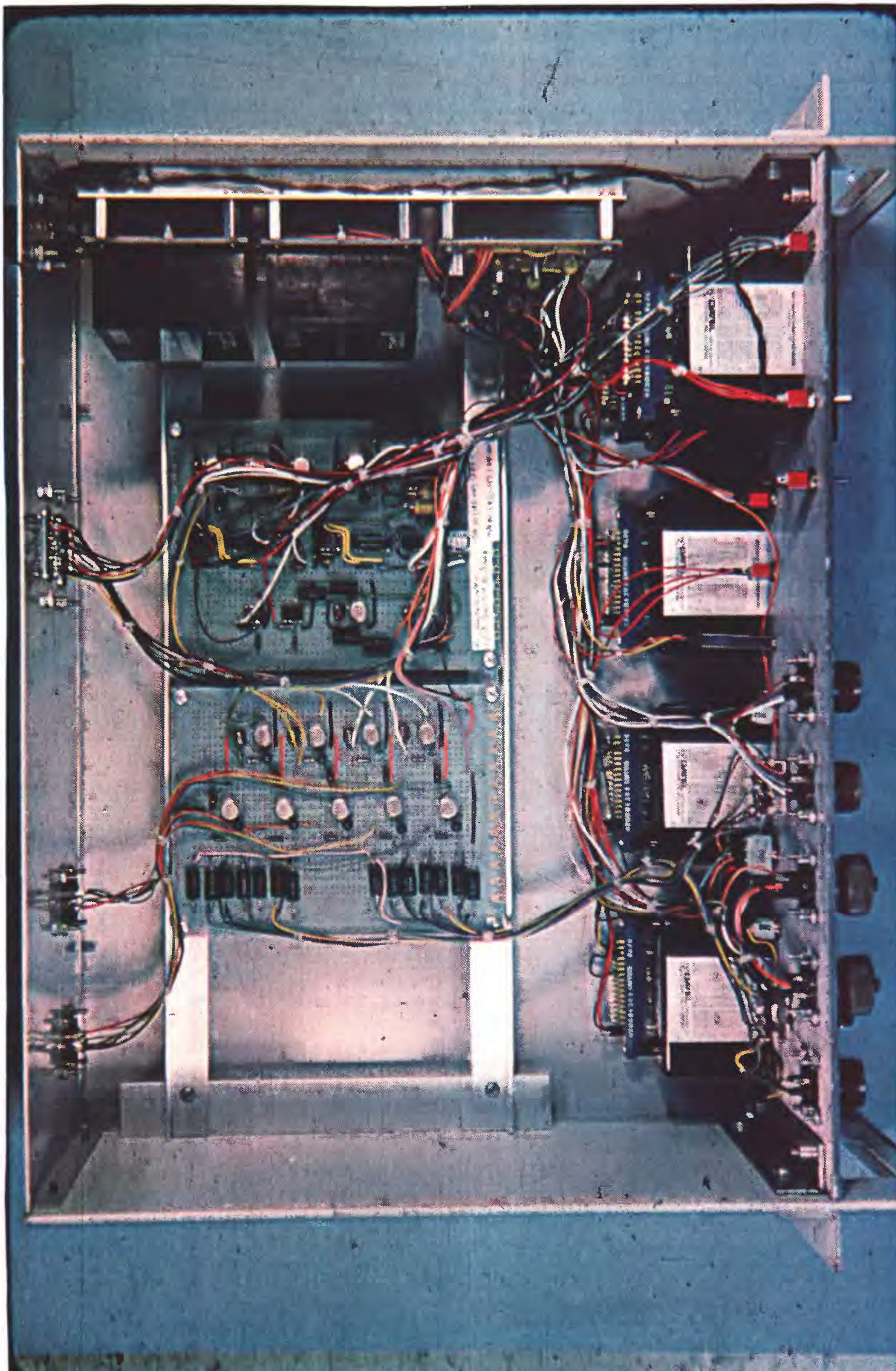


Figure 5. Top view: Panel 1.

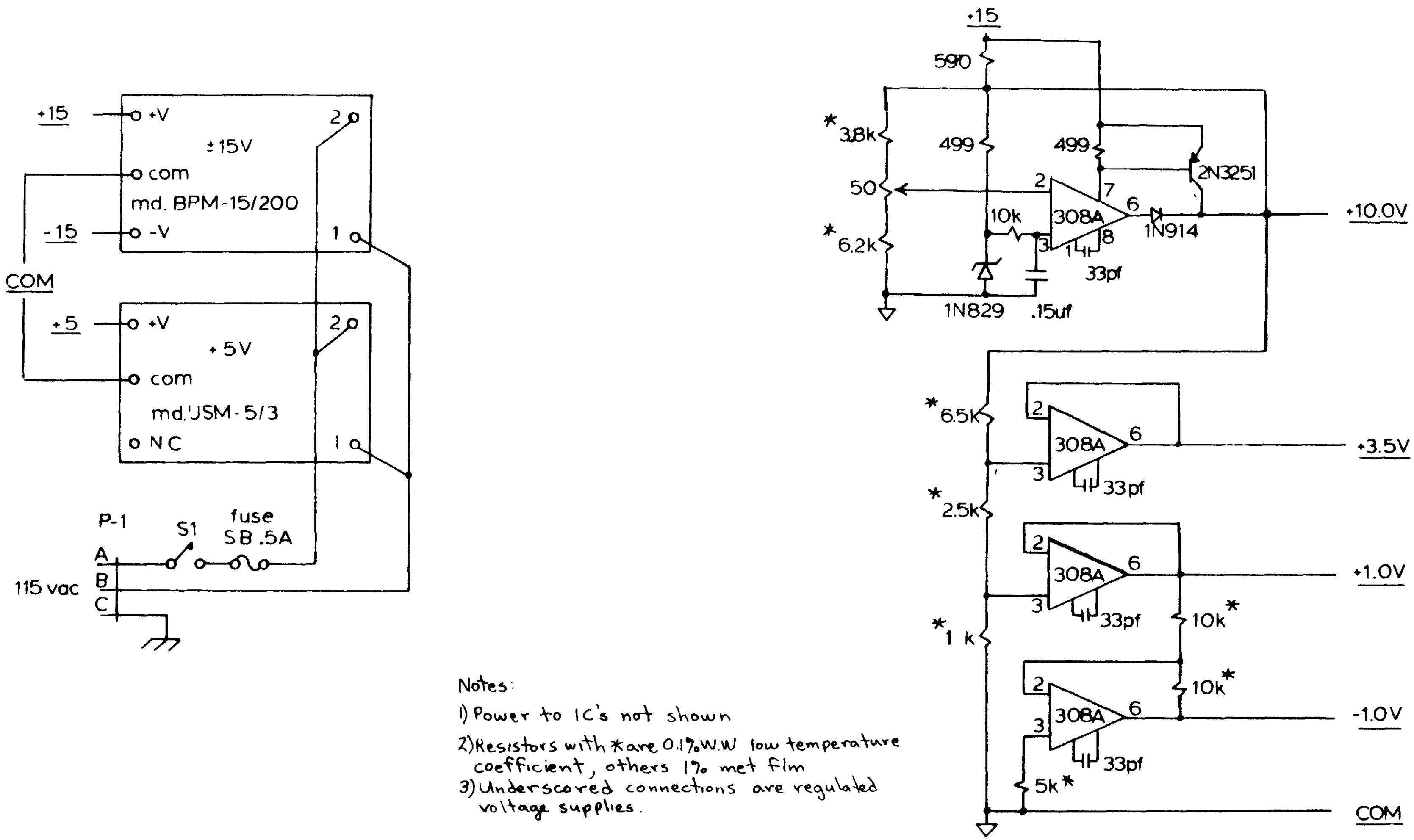
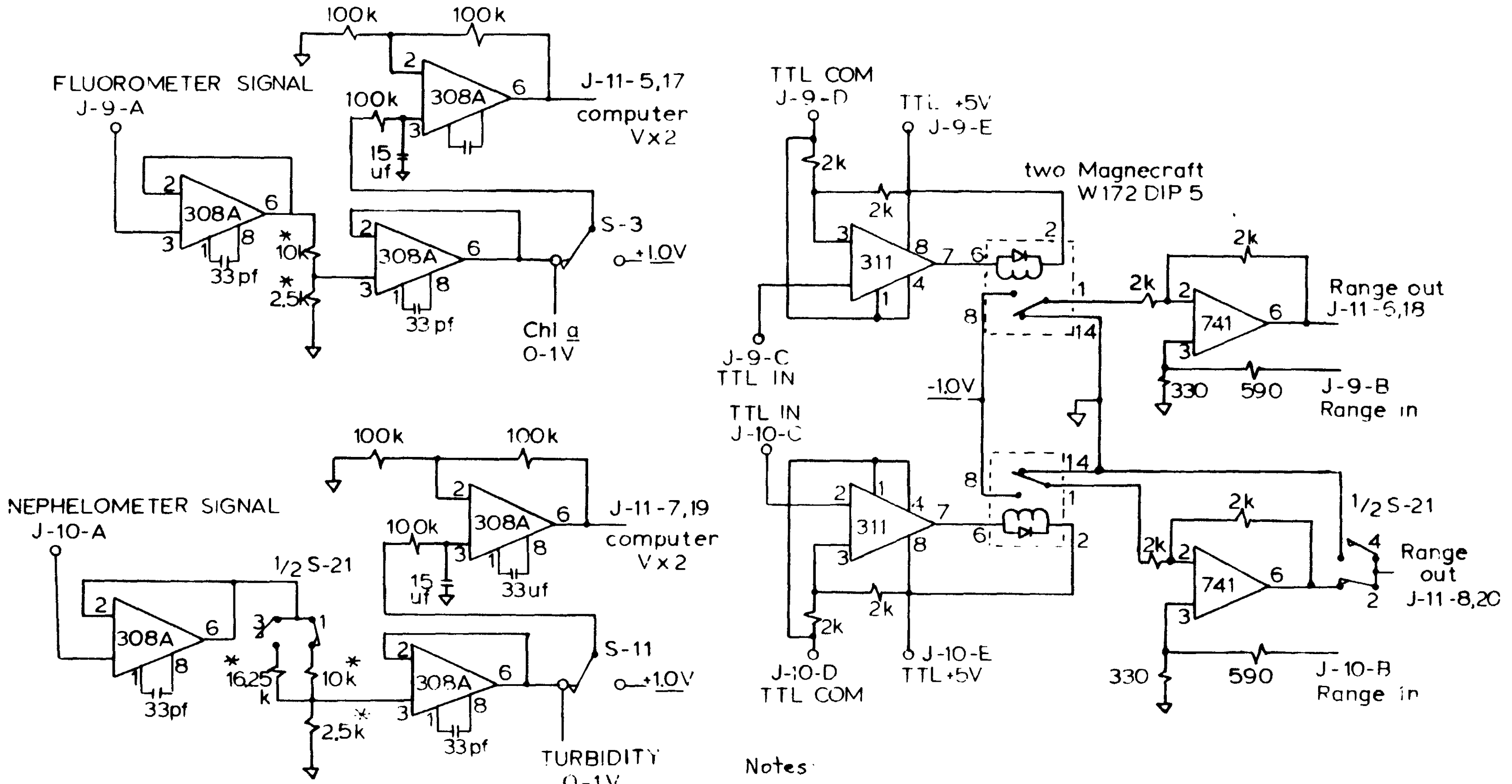


Figure 6. Circuitboard CB1 (Panel 1) or (Panel 2) schematic diagram.



Notes

1) DIP switch S-21 on circuit board, selects nephelometer input.
for Md.10 (1 & 2 ON) (3 & 4 OFF)
for Md 40 (1 & 2 OFF) (3 & 4 ON)

2) Resistors with * are 0.1% W.W, all others 1% met flm

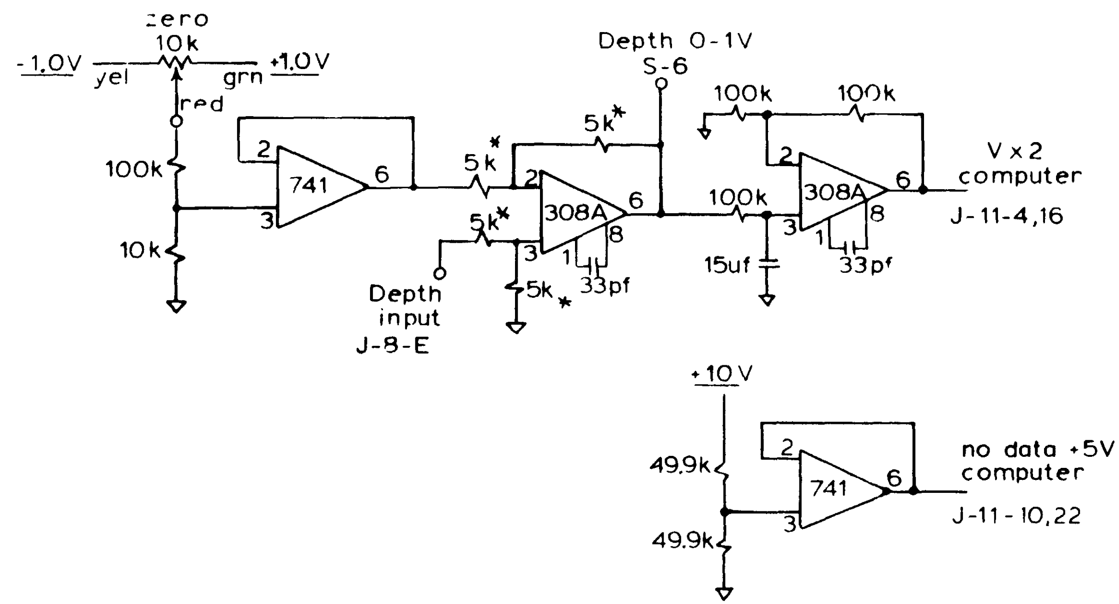
3) Power to IC's not shown

4) Underscored connections are at regulated voltage supply

Figure 7. Circuitboard CB2 (Panel 1) schematic diagram.

DRAWN BY L.D

DATE JUNE '80



Notes:

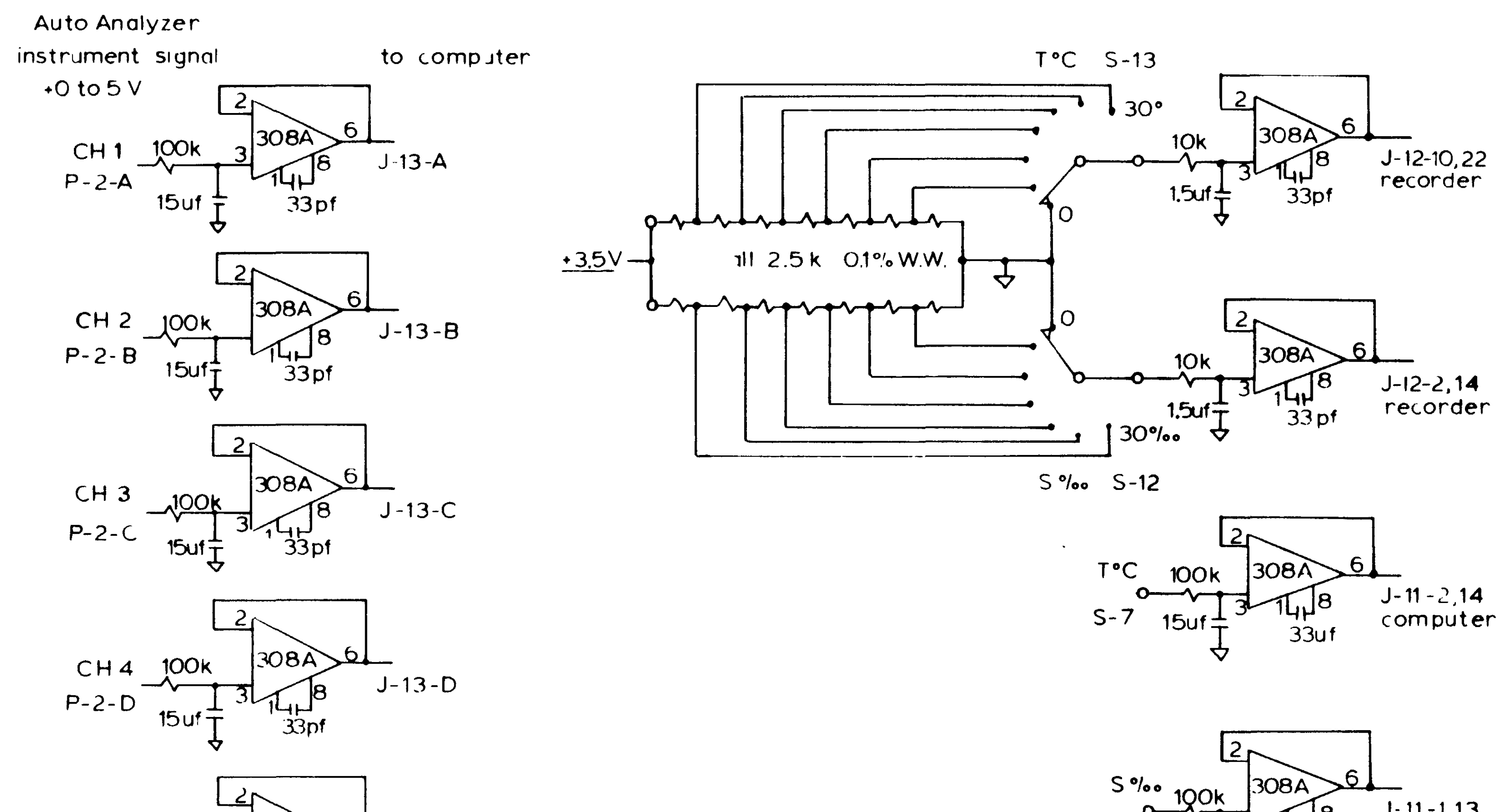
1) Resistors with * are 0.1%, all others 1%.

2) Power to IC's not shown

3) Underscored connections are at regulated voltage supply

Figure 8. Circuitboard CB2 (Panel 1) schematic diagram.

DRAWN BY L D
DATE JUNE '80



Notes:

1) Power to IC's not shown

2) Resistors are 1% met film unless indicated

3) Underscored connection is at regulated voltage supply

Figure 9. Circuitboard CB3 (Panel 1) schematic diagram.

DRAWN BY L D
DATE JUNE '80

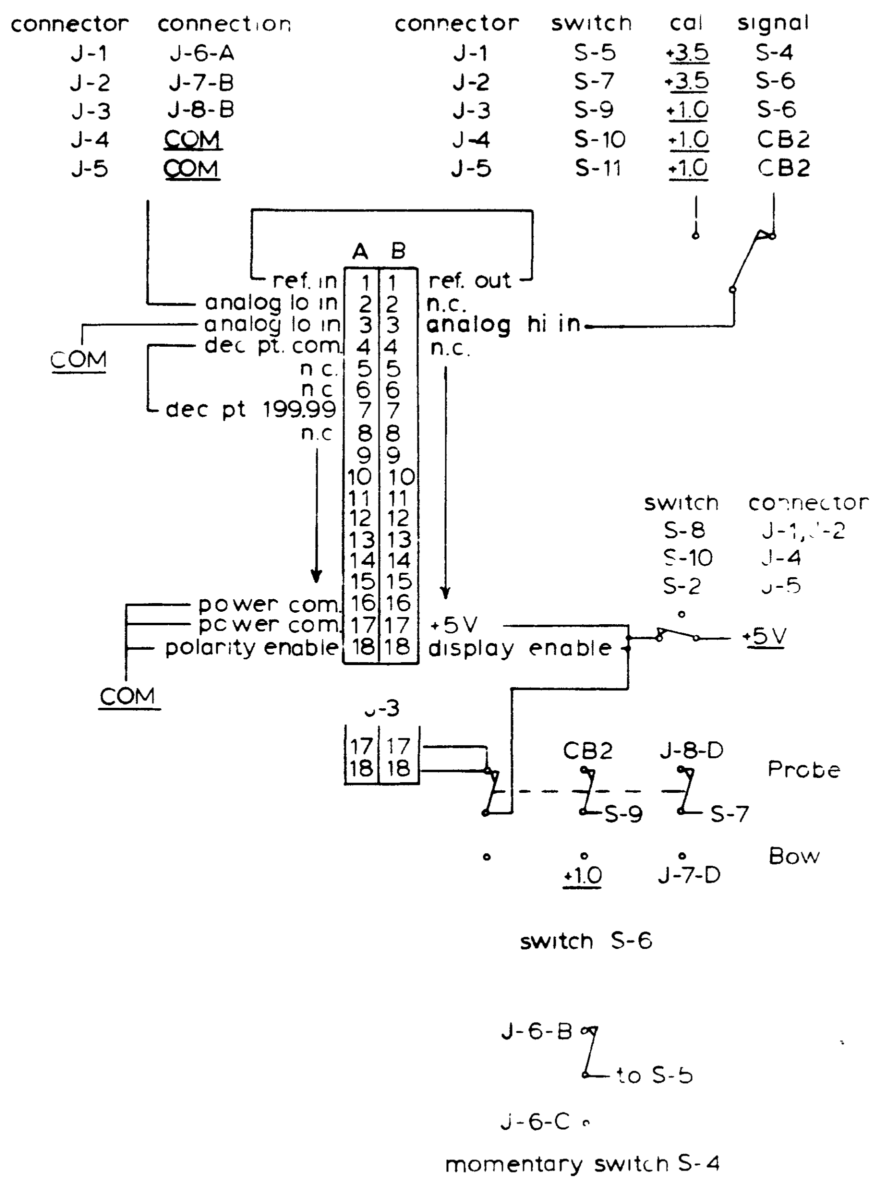
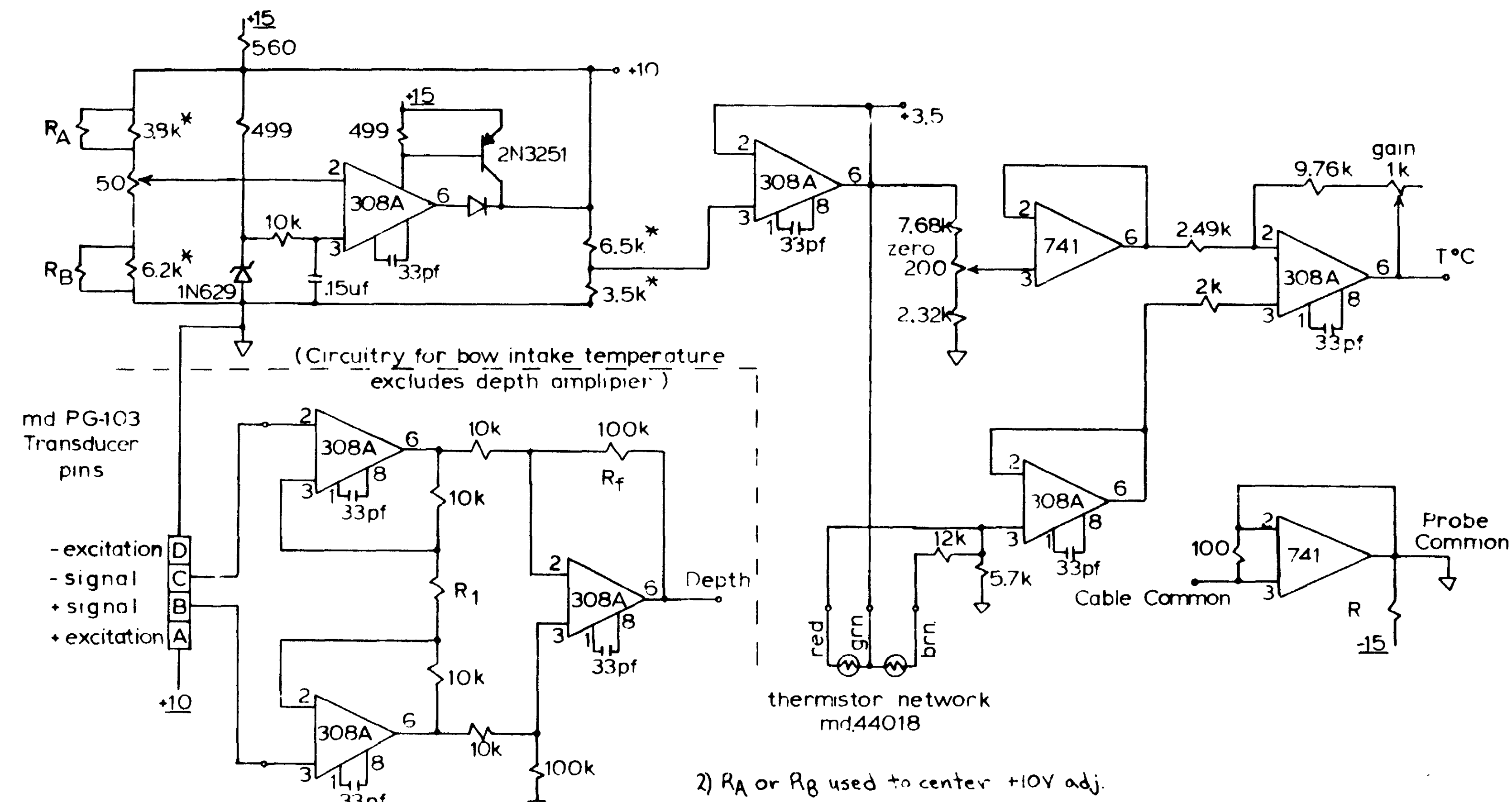


Figure 10. Digital panel meter and panel switch connections.

DRAWN BY L D
DATE JUNE '80



Notes:

1) Depth amplifier GAIN $= \frac{1.000\text{ V}}{\text{transducer full scale output (V)}}$
full scale output typically 0.025V to 0.030V.

$$R_1 = \frac{2 \times R_f}{\text{GAIN} - 10}$$

2) R_A or R_B used to center +10V adj.

3) Resistors with * are 0.1% WW., all others 1% met flm.

4) Balance ground amp by removing op amp and nulling voltage across 100Ω resistor with selection of R. R ≈ 1KΩ.

5) Power to IC's not shown

6) Underscored connections are at regulated voltage supply.

Figure 11. In situ temperature/depth probe and bow-intake temperature schematic diagram.

DRAWN BY L D
DATE JUNE '80

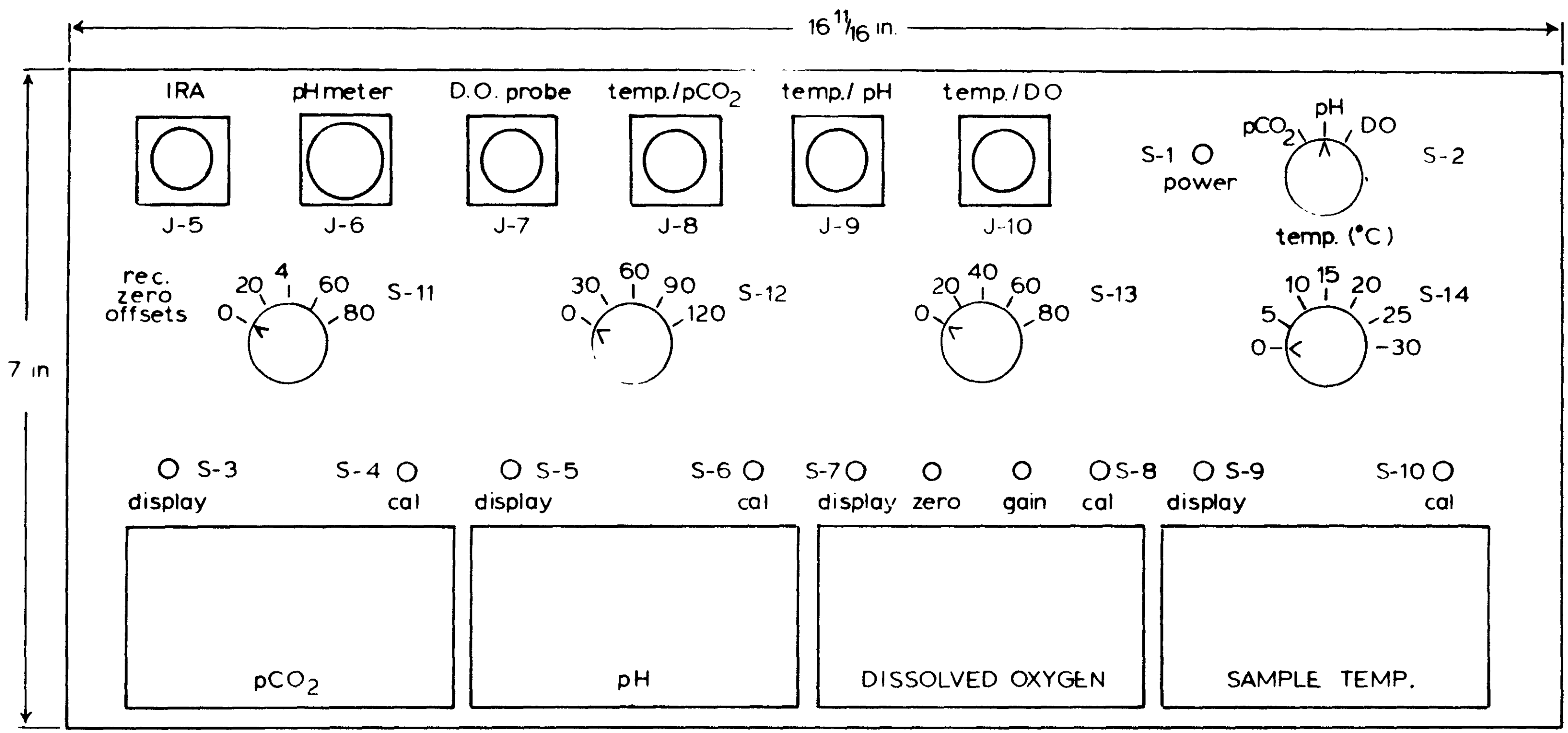


Figure 12. Front view layout: Panel 2.

DRAWN BY L.D.
DATE JUNE '80

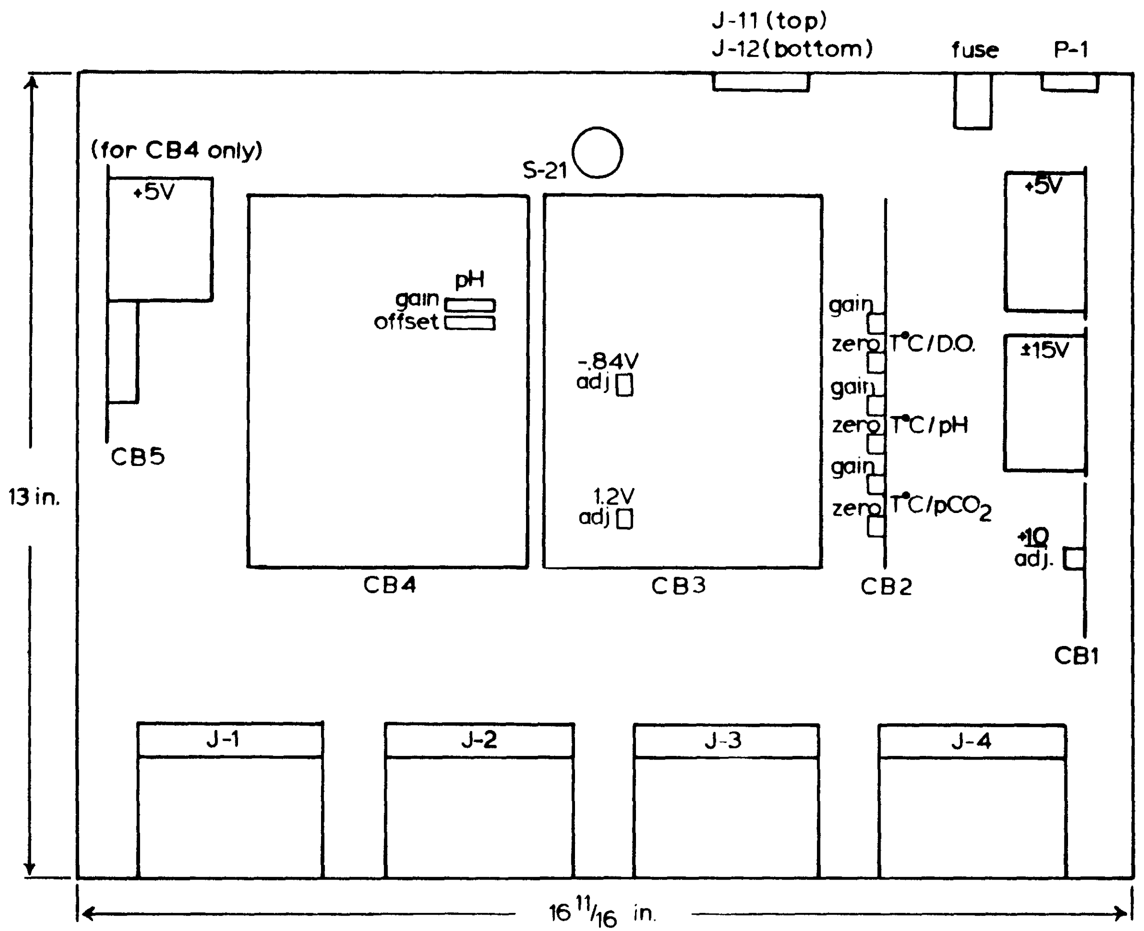


Figure 13. Top view layout: Panel 2.

DRAWN BY L D.
DATE JUNE '80

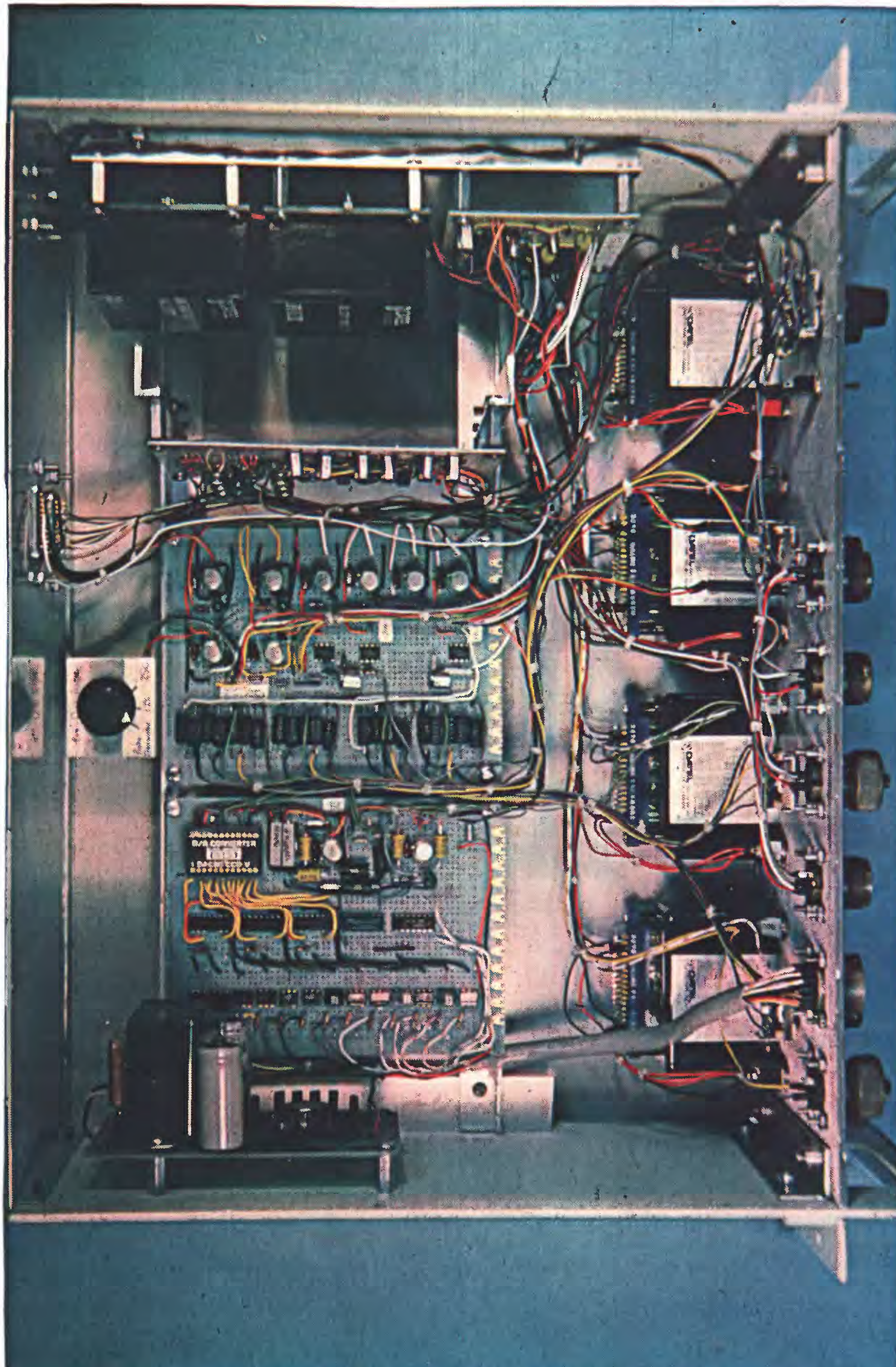


Figure 14. Top view: Panel 2.

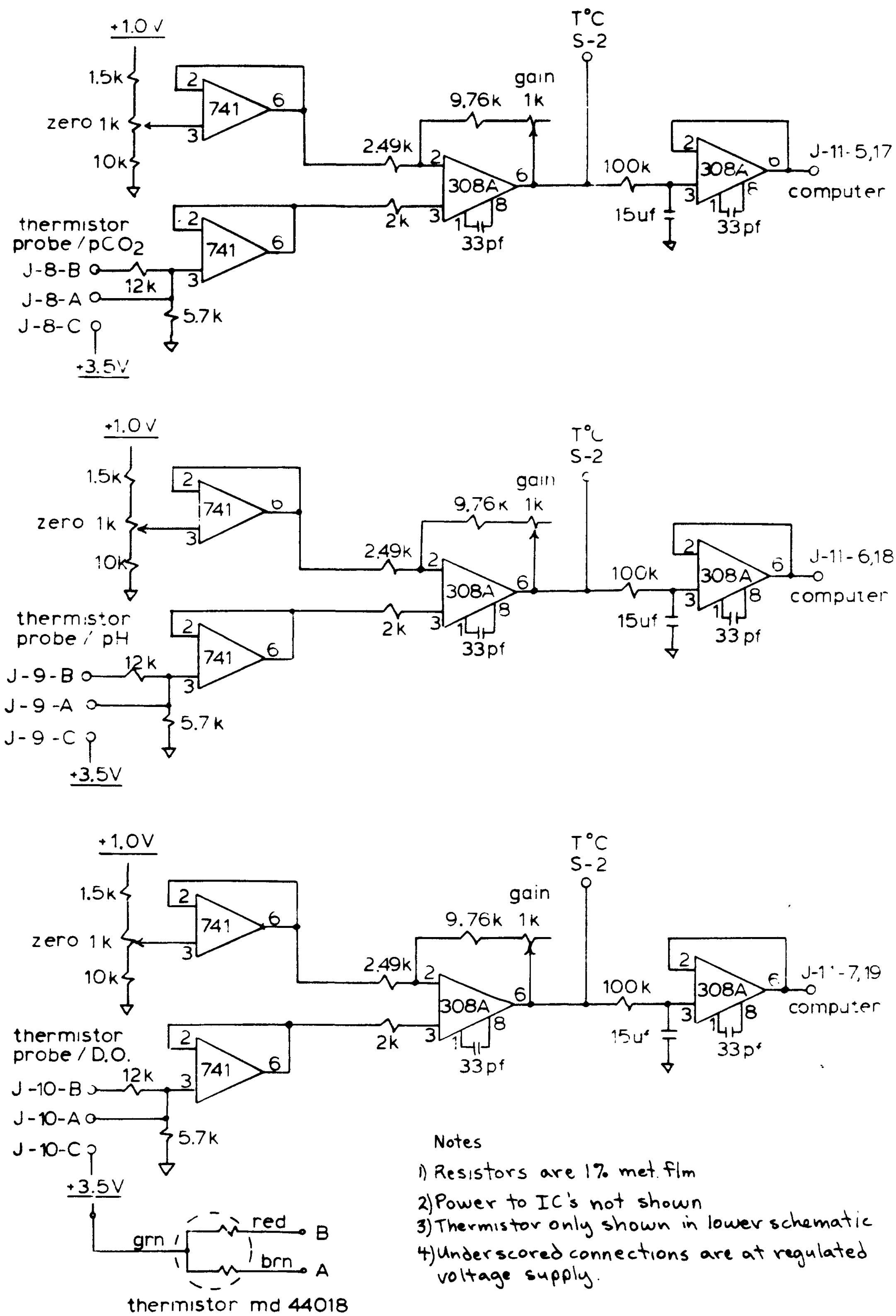
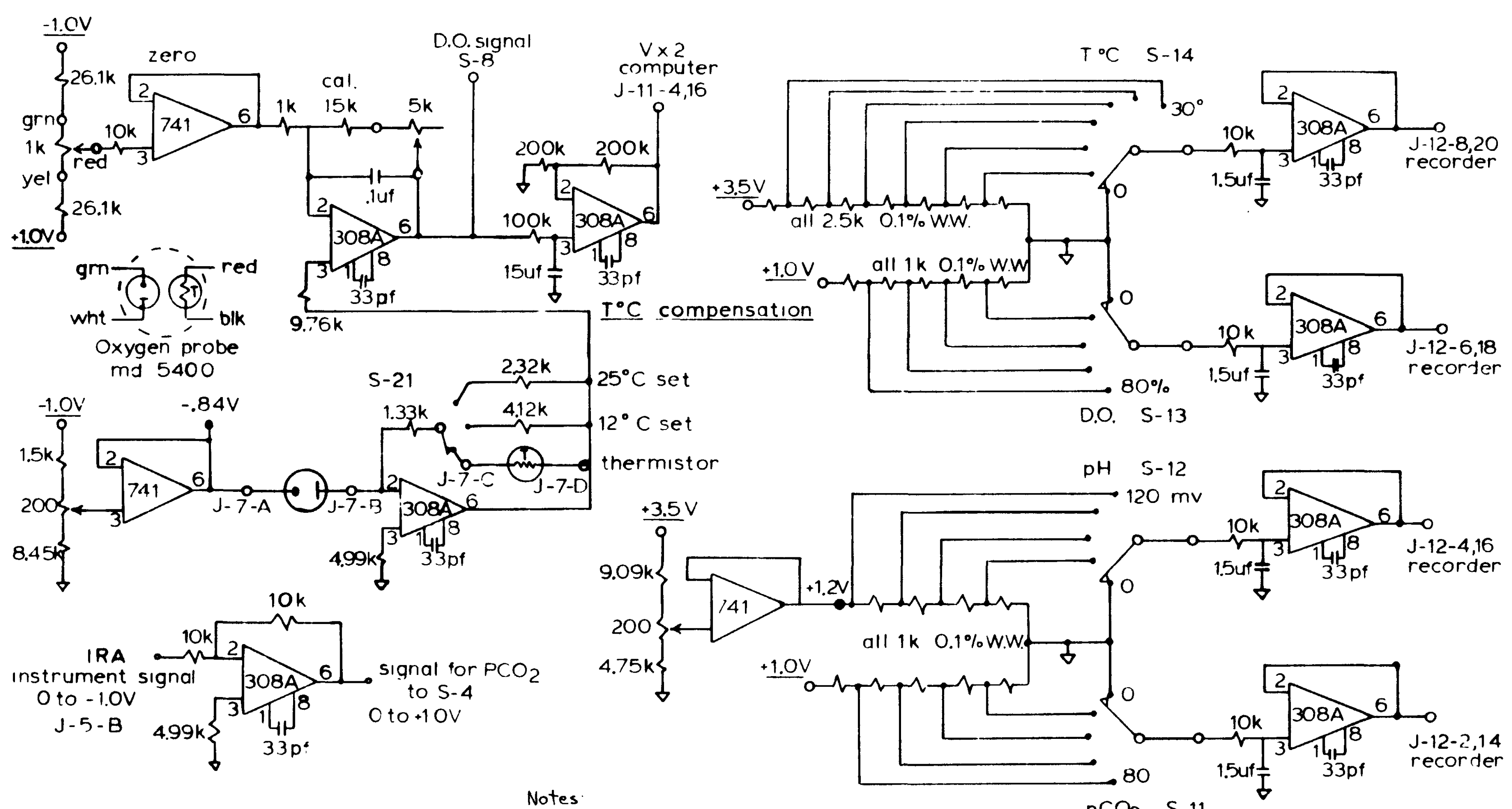


Figure 15. Circuitboard CB2 (Panel 2) schematic diagram.

DRAWN BY L.D
DATE JUNE '80



Notes:

1) Resistors are 1% Met flm unless indicated

2) Power to IC's not shown

3) Underscored connections are at regulated voltage supply.

Figure 16. Circuitboard CB3 (Panel 2) schematic diagram.

DRAWN BY L.D.

DATE JUNE '80

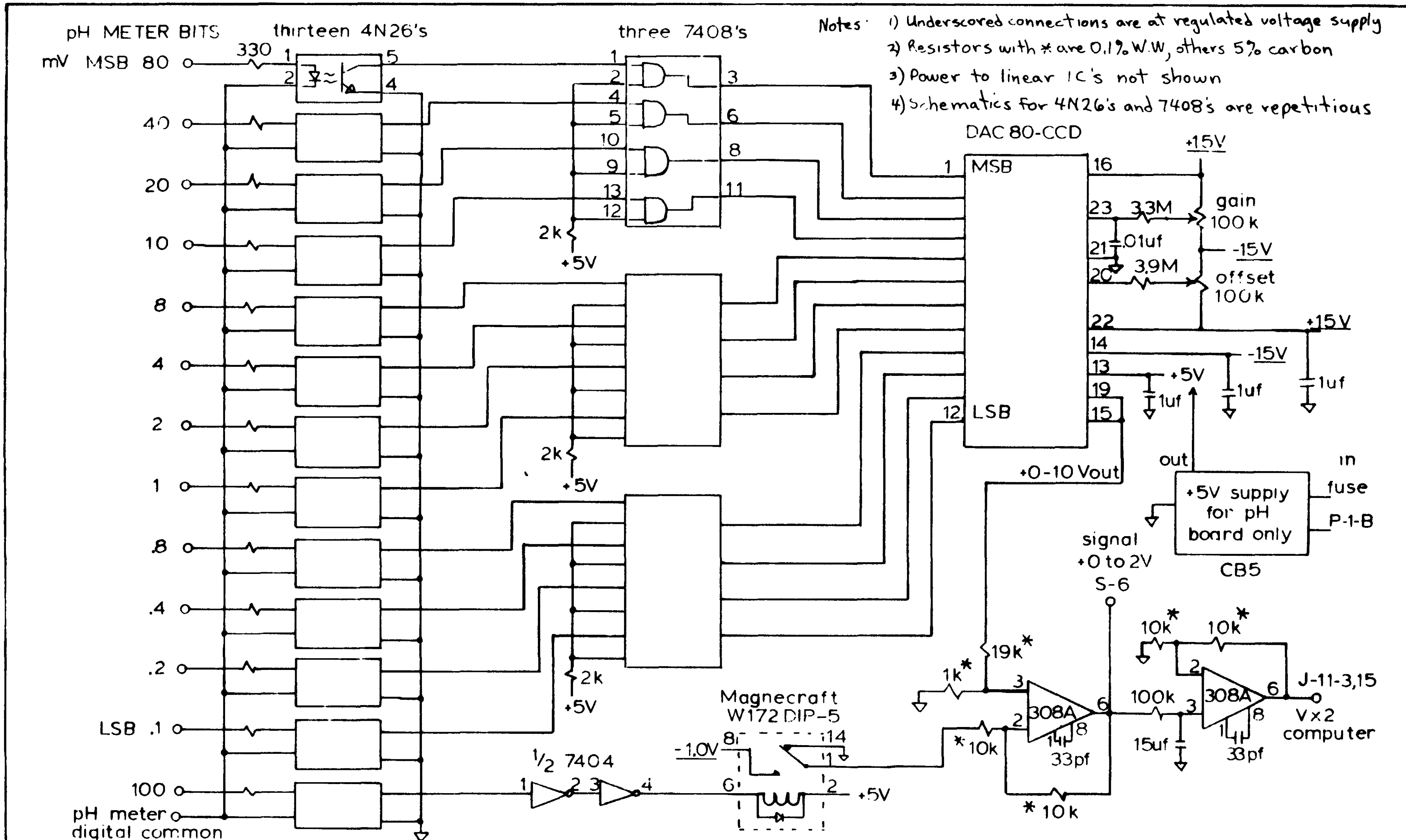
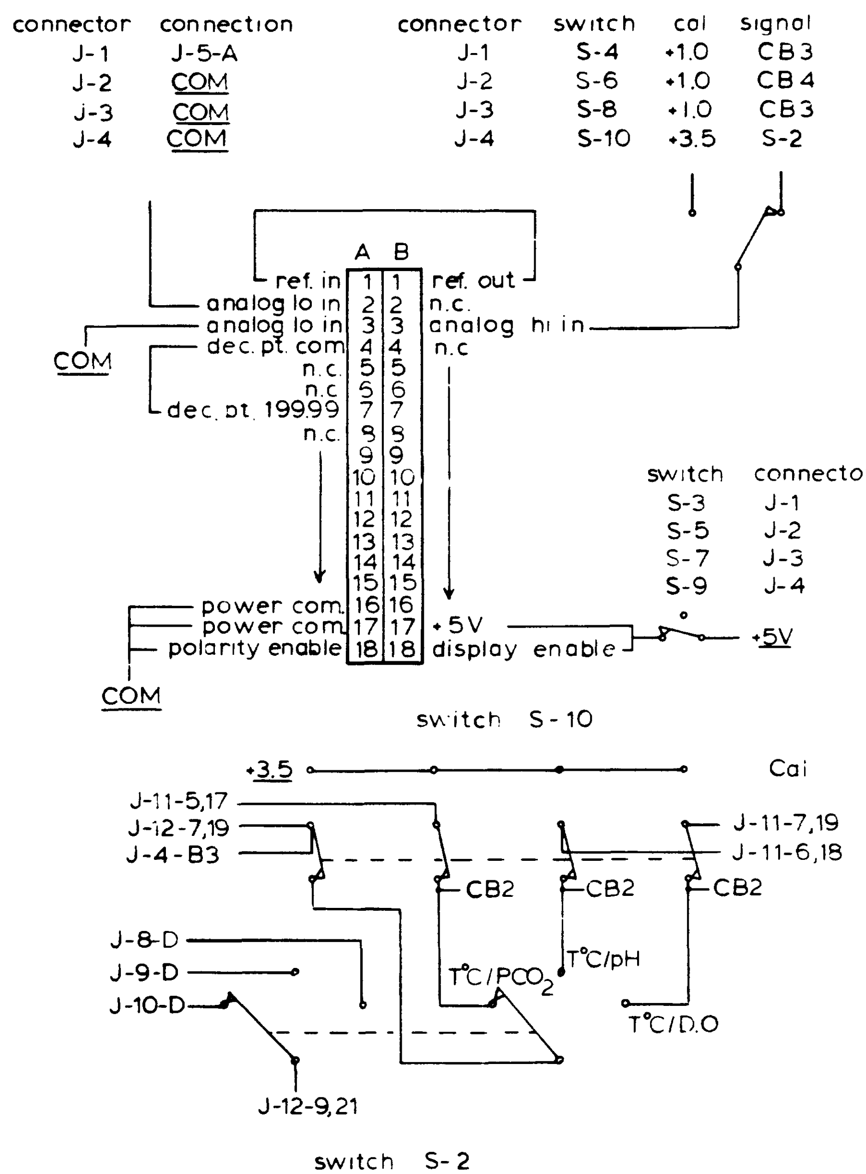


Figure 17. Circuitboard CB4 (Panel 2) schematic diagram.

DRAWN BY L D
DATE JUNE '80



Note: 1) Underscored connections are at regulated voltage supply

Figure 18. Digital panel meter and panel switch connections: Panel 2.	DRAWN BY L. D. DATE JUNE '80

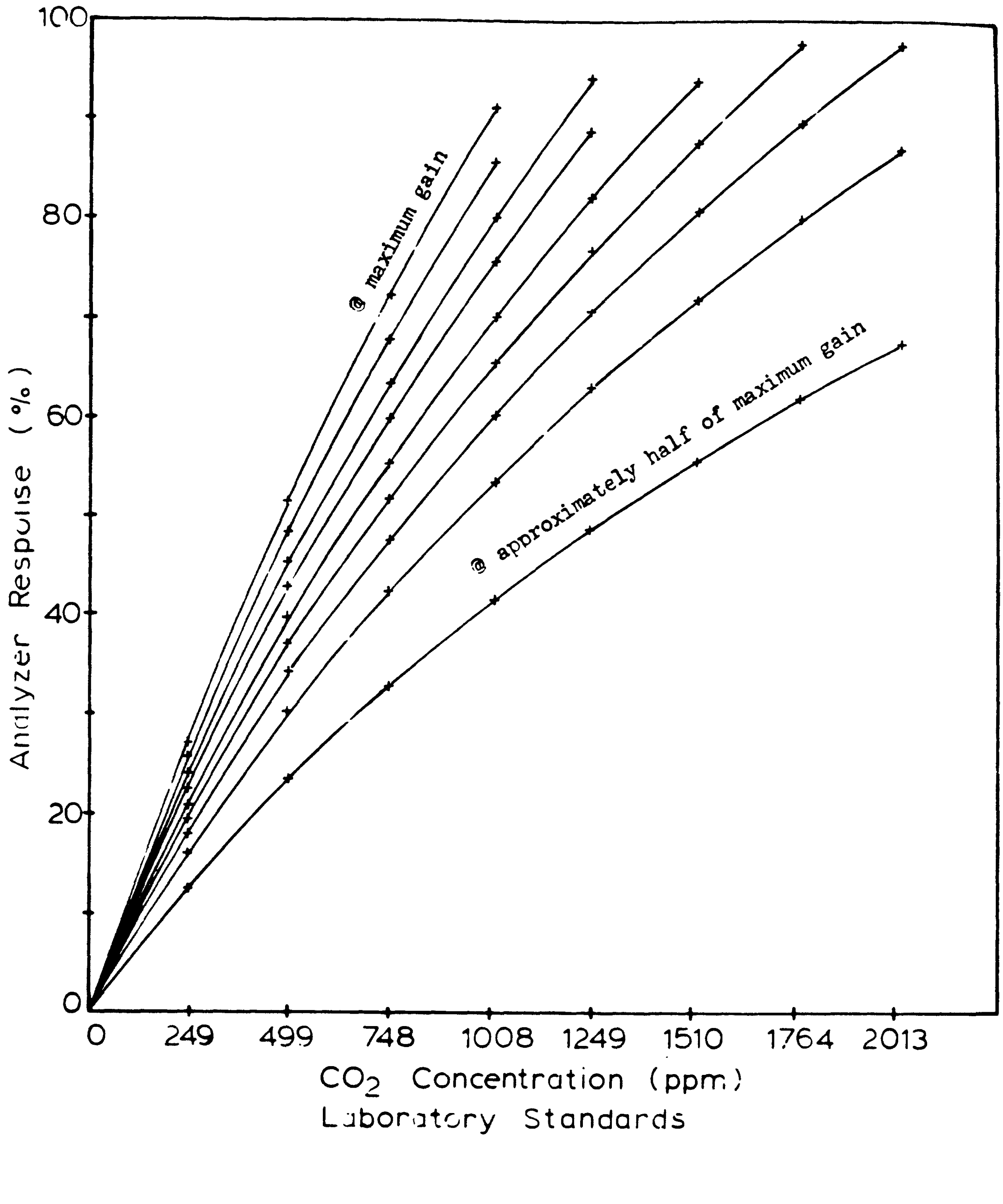


Figure 19. Infrared analyzer response curves at various gain settings.

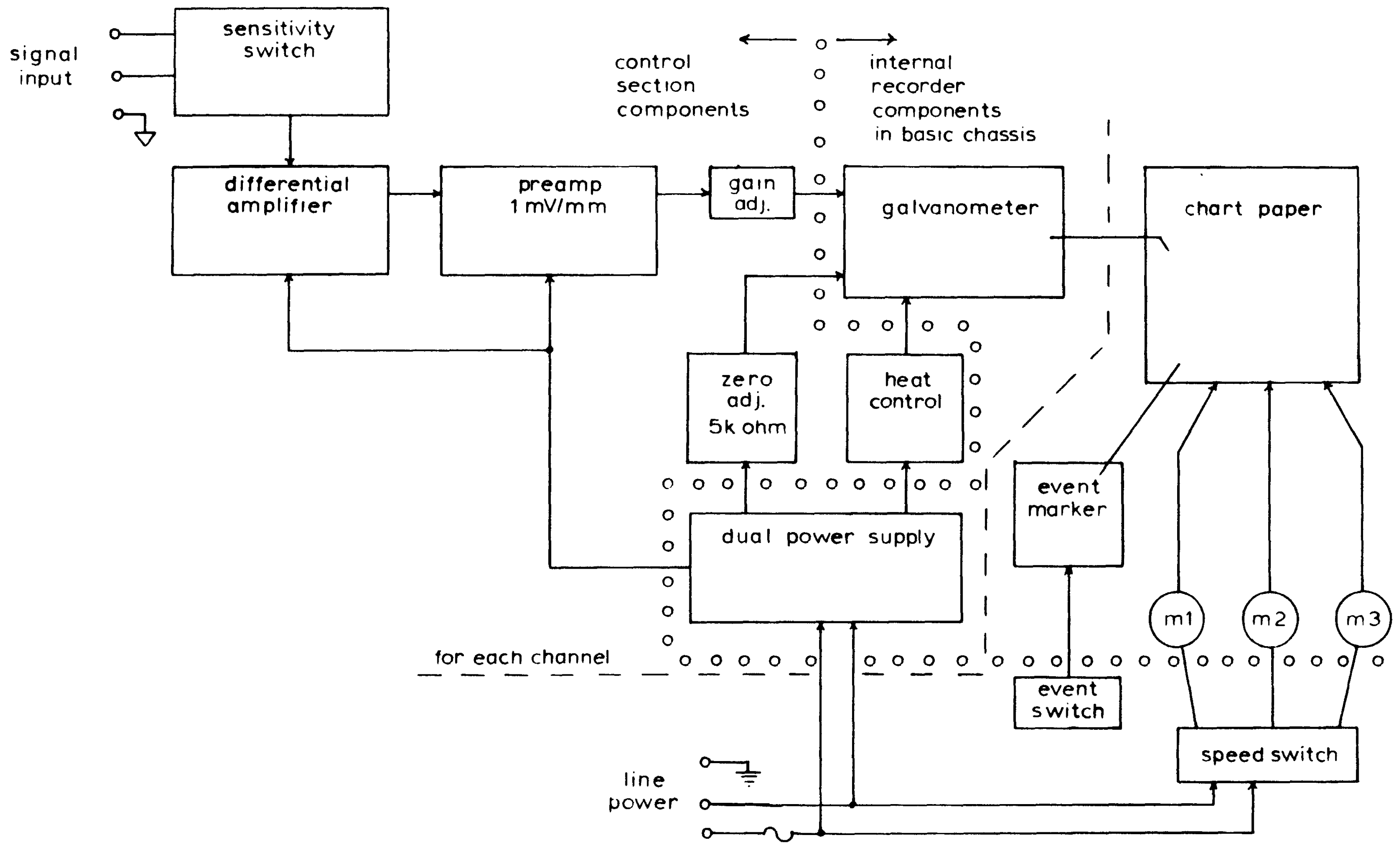


Figure 20. Block diagram of recorders.

DRAWN BY L.D.
DATE JUNE '80

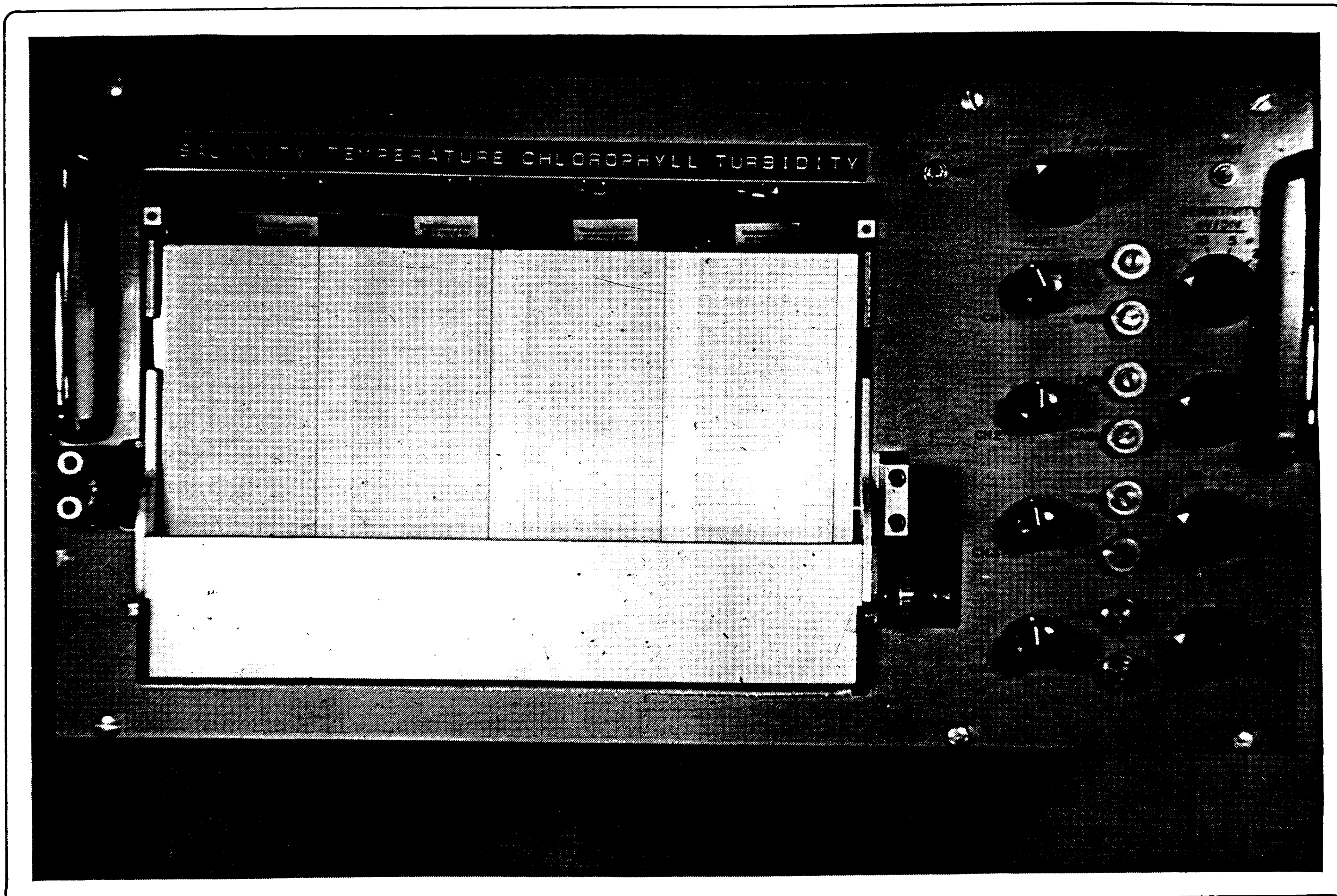


Figure 21. Front view: Recorders.

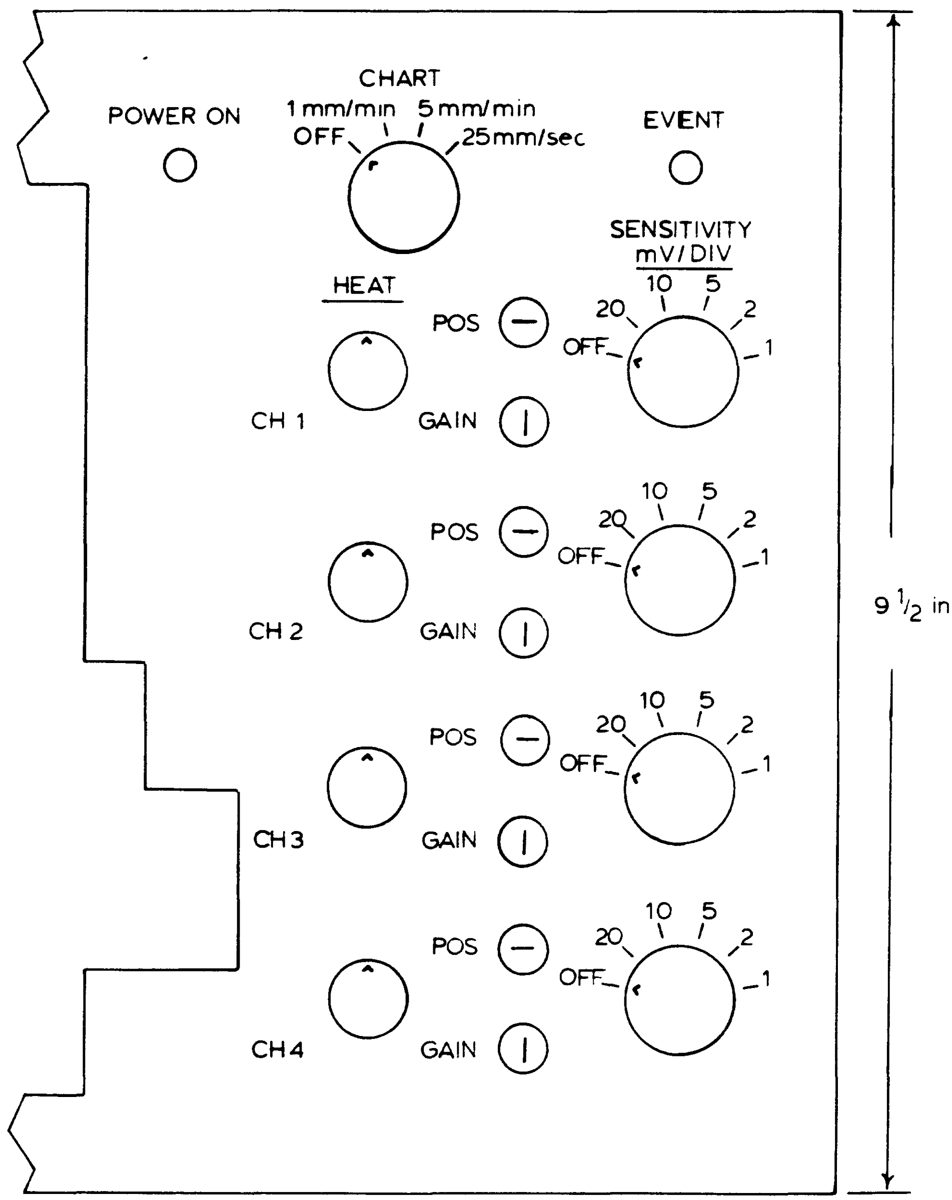


Figure 22. Front layout of control section: Recorders.	DRAWN BY L D. DATE JUNE '80

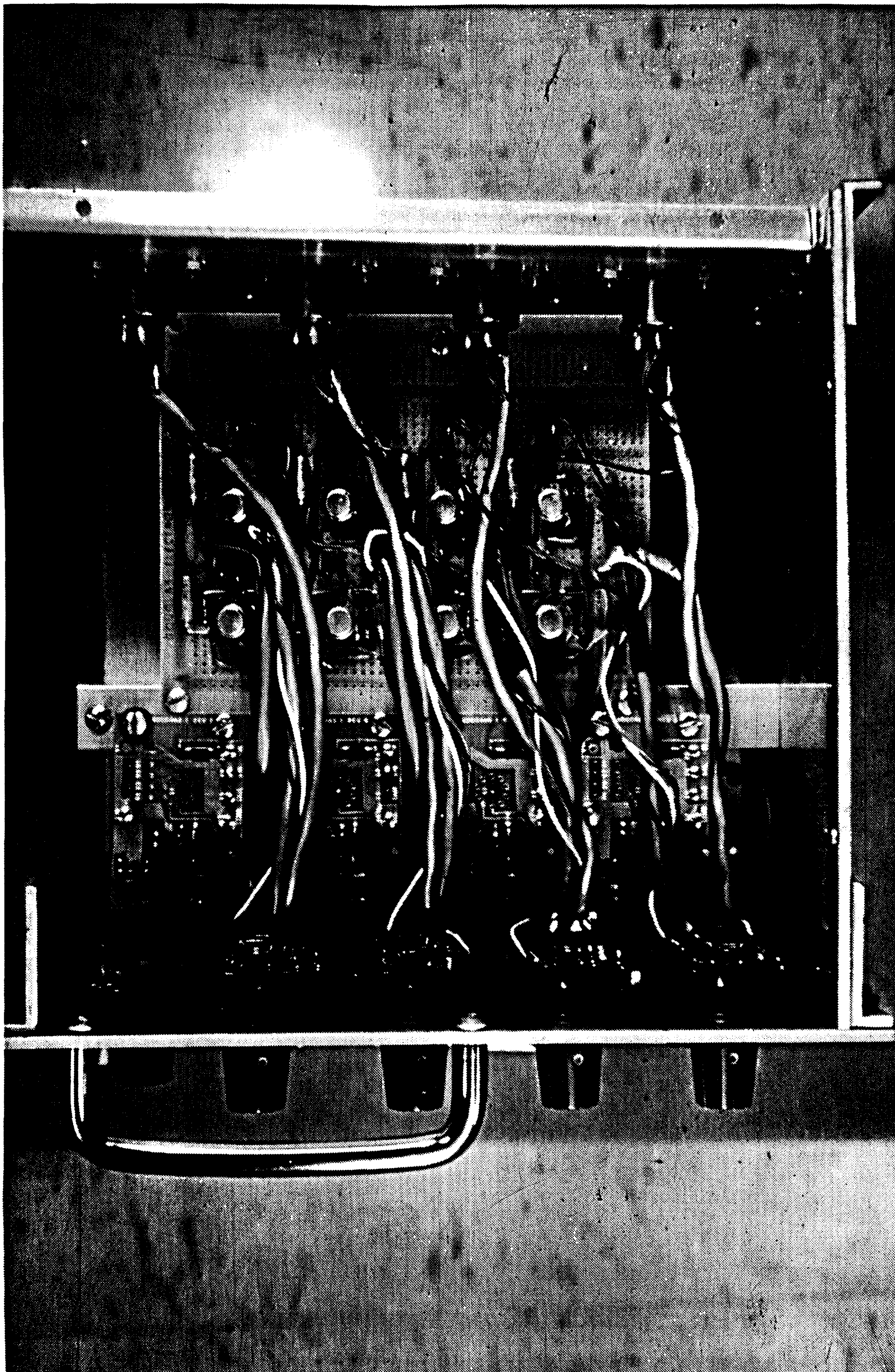


Figure 23. Side view: Recorders.

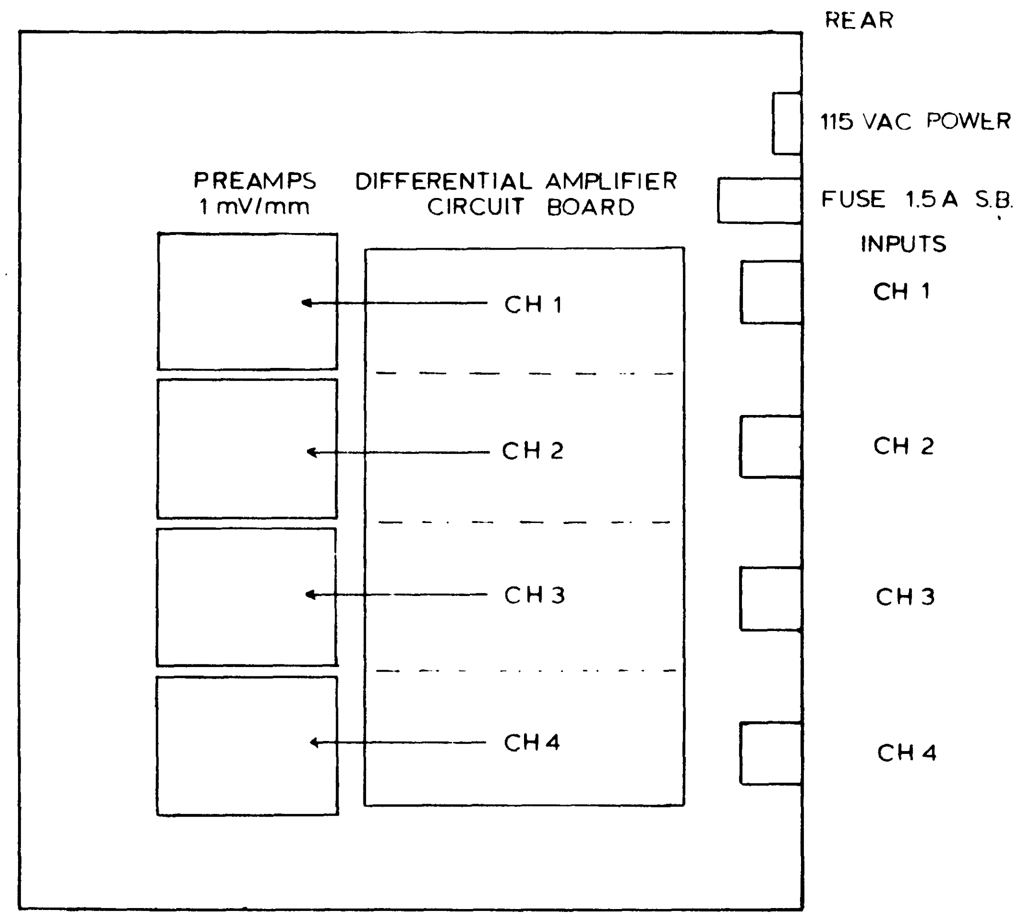


Figure 24. Side layout of control section: Recorders.

DRAWN BY L D
DATE JUNE '80

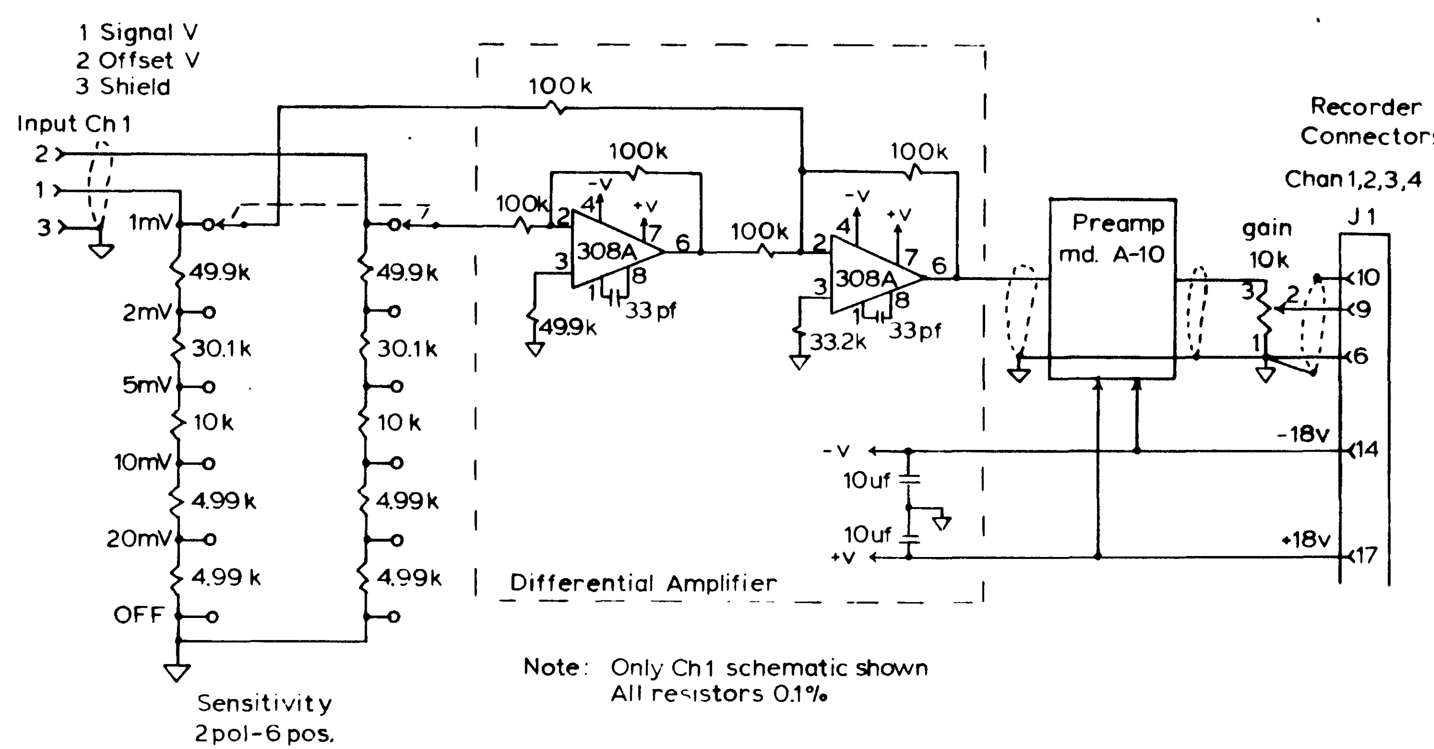
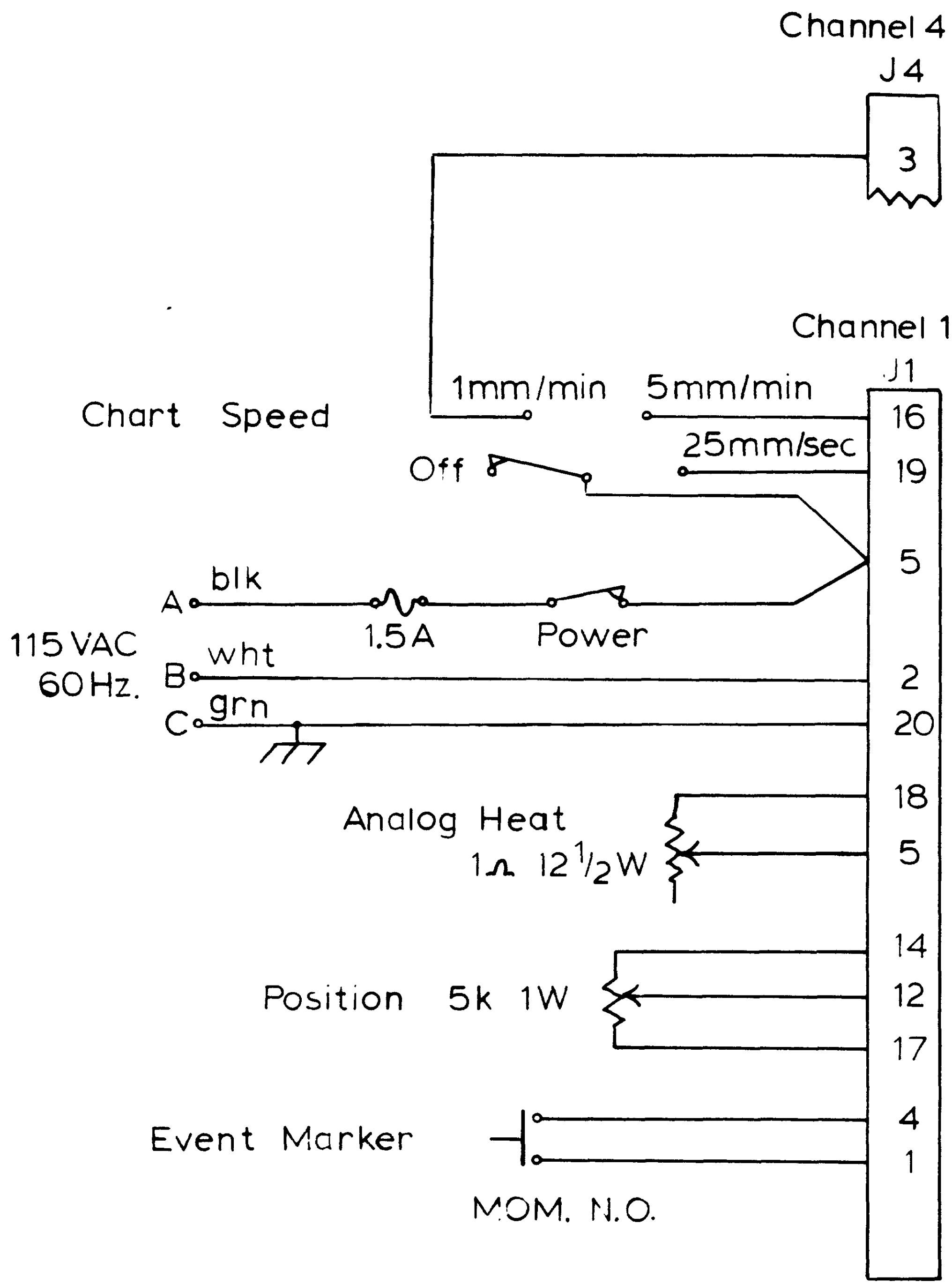


Figure 25. Attenuation and amplifier schematic diagrams: Recorders.

DRAWN BY L.D.
DATE JUNE '80



Note:
115VAC input, heat adjust, and position adjust are shown for channel 1 only. Chart speed and event marker are connected as shown.

Figure 26. Wiring diagram of controls to recorder connectors.

DRAWN BY L.D.
DATE JUNE '80