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METEOROLOGICAL INPUT DATA PROCESSING SYSTEM

A part of the electronic model
for tides and storm surges

S. Ishiguro
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ABSTRACT

The meteorological input data processing system is a part of the new electronic model which is used for the dynamic analyses of tides and storm surges in most on-continental-shelf seas. This model method offers the solution of the tide and surge equations in the differential (not difference) forms at a high speed (typically 10 milli seconds for a 10-day surge). The meteorological input data processing system is used for converting meteorological input data in an arbitrary form (e.g. the data of atmospheric pressure represented by a set of isobar maps) into the form which can be processed by the model.

The system consists of the data editing unit, computing unit, and vector plotting unit, supported by a keyboard, tape-punch, tape-reader and xy plotter.

The data editing unit is used for changing the order of data and editing it with other data, and also for producing copies of data at any stage of the data handling.

The computing unit consists of several sub-computing units which make it very versatile. It is used for computing the input data to the stage just before its dynamic computation (which is carried out by the main computation circuit in the model). For example, the data of wind field can be computed from the data of atmospheric pressure field, by setting this unit appropriately. The stress of the water surface due to the wind field, the surge height within each finite area and time, etc. can also be computed. The speed of computation is much faster than the speed of data transfer (typically a few micro seconds for each set of computation).

The vector plotting unit has been designed to display the data in vector quantity at any stage of the computation, so that the data can be checked before the final surge heights and currents are obtained (e.g. the computed wind field can be compared with observed wind data). The plotting speed is limited by the xy plotter (about 1.3 vectors per second at the moment).

The system is contained in a case of $7.7 \times 21 \times 23$ cm^3 (weight 3.3 kgr), and operated by a 240V AC power line.

The principle, basic design scheme, circuit description, physical design, performance, operational procedure of the system, and some examples of output are described in this paper. The system has been applied successfully to a practical project.

1. INTRODUCTION

The electronic model for tides and surges (Ref. 1) requires a set of meteorological input data to simulate a storm surge. Available meteorological data, however, generally varies widely in its forms (e.g. diagram, table, tape or punched card, each of which contains data in various orders), while the form required for the model is almost fixed. This paper describes an electronic system by which meteorological data in various forms can be converted into a usable form for the model.

The system has been designed to carry out three types of operation:

1. To edit input data in an arbitrary format to the format required for the main computation circuit of the model.

2. To compute the input data before the full dynamic computation is carried out by the main computation circuit.

   For example, wind field data for the sea surface is computed from atmospheric pressure field data alone. The wind field data can then be combined with the pressure field data, also by this system.

3. To display the data at any stage of processing so that the data can be checked against other references.

   For example, computed wind data can be compared with observed wind data, before it is applied to a surge computation.

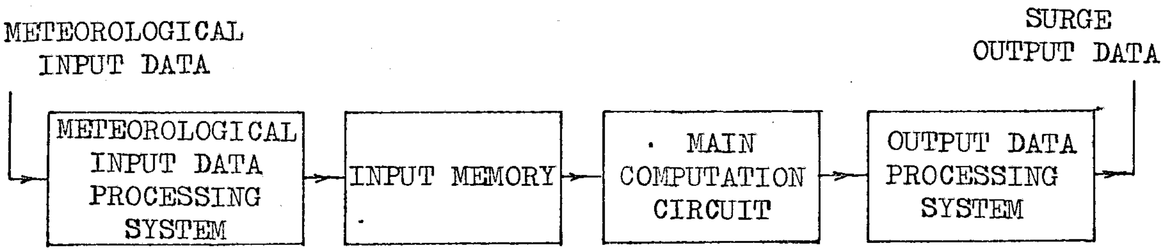


Fig. 1 Position of the meteorological input data processing system in the whole model.

Fig. 1 shows the position of the meteorological input data processing system in the whole system. The system consists of

Data editing unit,

Computing unit, and

Vector plotting unit,

supported by a keyboard, tape-punch, tape-reader, and xy plotter. The tape-punch and tape-reader which are used in the present arrangement can be replaced with a magnetic tape recorder/reader, if necessary.

This system has been used successfully in the analysis of the February 1953 storm, which shows the importance of the gradient wind in an intensive surge case (Ref. 3).

2. DATA EDITING UNIT

The data editing unit has been designed to convert input data in arbitrary format into the format required for the first stage of computation which is carried out by the circuit described in chapter 3.

The basic principle of the unit is:-

1 to write the input data into a random access memory (RAM) in the order of the data reception,

2 to read the data in the memory in the order required, and

3 to combine the read data with other data.

This unit can also copy a tape with an arbitrary code up to 8-bit per word, while few standard tape handling apparatus accept an arbitrary code.

The memory has only 256 addresses, but this is more than enough for this application. Input data is usually related to meteorological conditions which are expressed by values on meteorological grids on maps with, typically, hourly intervals. Therefore, the editing operation can be repeated for each map without changing the format. The total number of the meteorological grids for which useful information is available is less than 100 for the seas around the British Isles at the moment.

2.1 Scheme of the data editing unit

Fig. 2 shows the block diagram of the data editing unit, and Fig. 3 shows its essential parts.

Four types of input tape are used:-

Tape A which contains input data only, and is used for writing it into the memory.

Tape B which contains addresses of the memory, and from each of which a word in the memory is read.

Tape C which contains the addresses as Tape B, but also contains another set of input data which is mixed with the first set of data.

Tape 0 which contains the start code only, and used for checking the contents of the memory.

The data editing unit works in three modes:-

1 Input data given by tape A goes directly to the output, or through the memory, without changing the order of words.

2 Input data given by tape A goes to the output, in the order specified by tape B.

3 Input data given by tape A goes to the output, in a specified order given by tape C, and data on tape C also goes to the output in a specified condition.

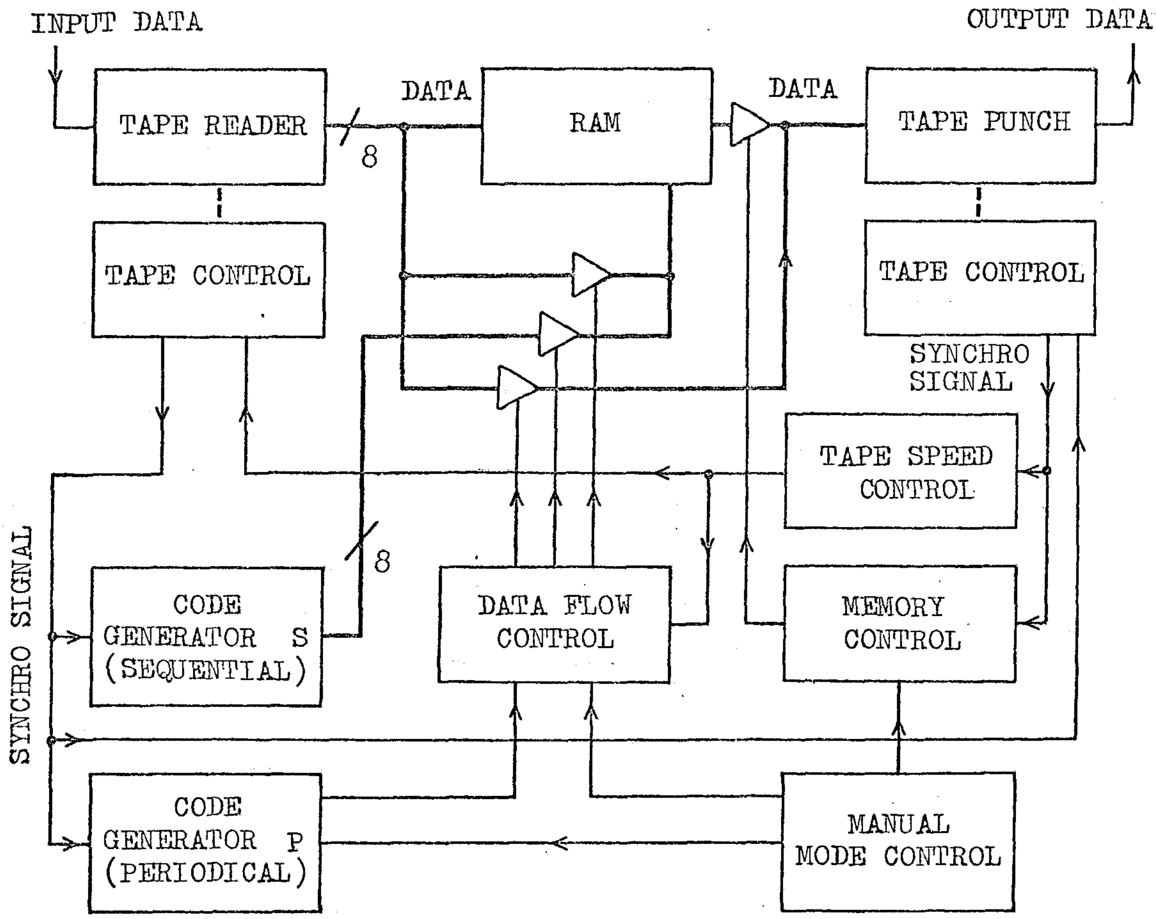


Fig. 2 Block diagram of the data editing unit.

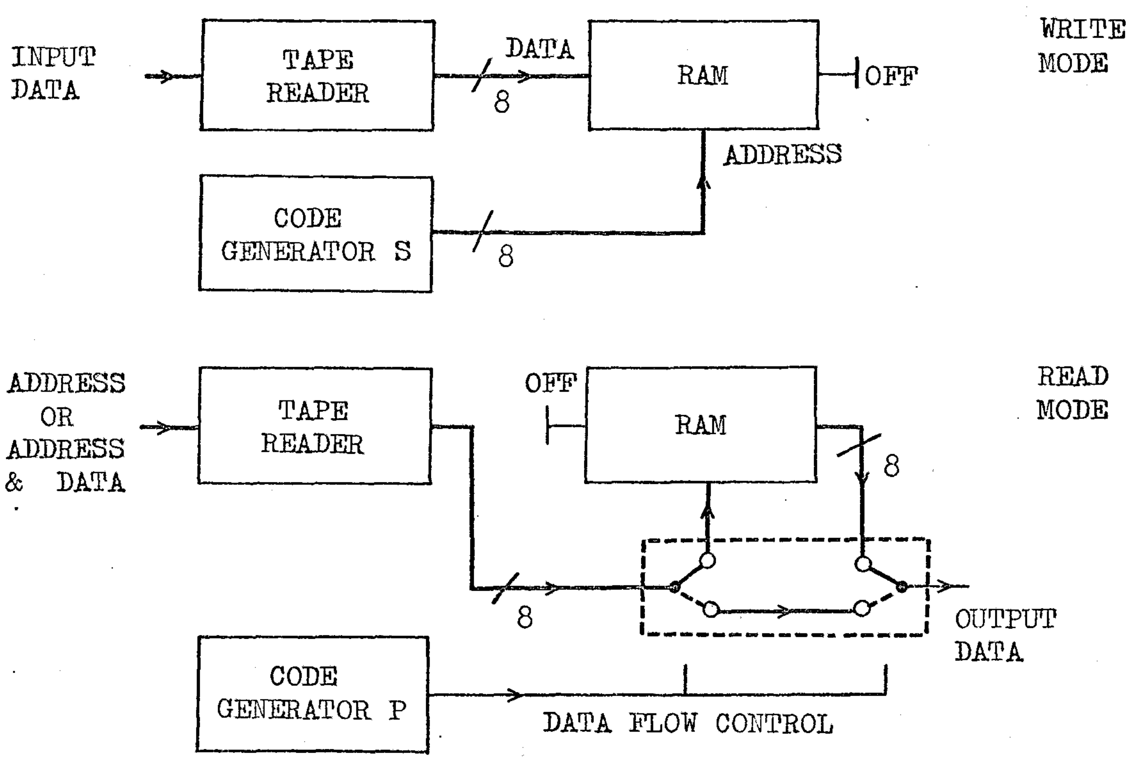


Fig. 3 Essential parts of Fig. 2 for the write and read modes.

The writing of the memory is carried out by feeding the input data into the memory, and by selecting its address with code generator S which generates a sequential binary code.

Read mode 1 is carried out by selecting the memory address with code generator S and by reading the memory.

Read mode 2 is carried out by feeding the address code on tape B into the memory address, and reading each word corresponding to each address.

Read mode 3 is carried out by feeding the address code on tape C into the memory address through the switching circuit which is controlled by code generator P. When the switch is in the 'output side' position, the data on tape C goes directly to the output. The code from code generator P is programmed so that the address and data on tape C are separated.

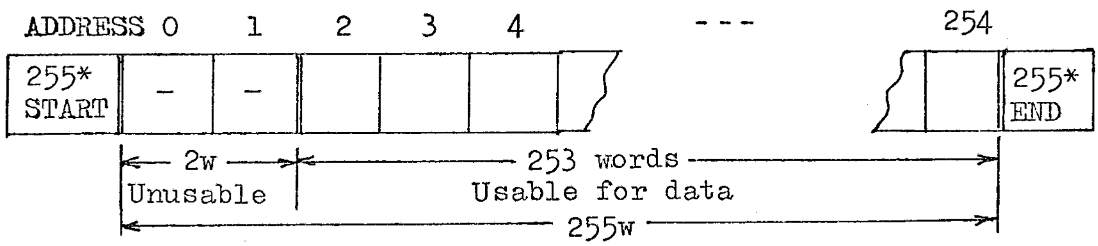
The timing of the RAM is controlled by the memory control circuit which synchronizes with the tape-reader, tape-punch or manual mode selector. The write speed of the whole unit is limited by the tape-reader (500 w/s max.), and the read speed is limited by the tape-punch (75 w/s max.) with the tape-reader in a step-by-step mode.

In order to achieve an optimum speed of operation, the whole unit is normally synchronized with the tape-reader. Only when the tape-punch is activated (even for punching a single word), the whole unit is instantaneously synchronized with the tape-punch, then returns to the first state immediately. This action is controlled by the tape control circuit for the tape-reader.

2.2 Formats of the tapes for standard operations

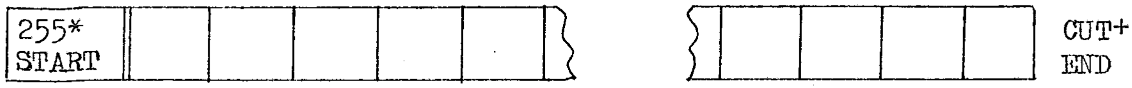
The formats of tapes A, B, C and 0 are described in this paragraph. The details of the format for Tape C varies from case to case, but a typical format is shown as an example.

Tape A For the sequential writing of data into the RAM.



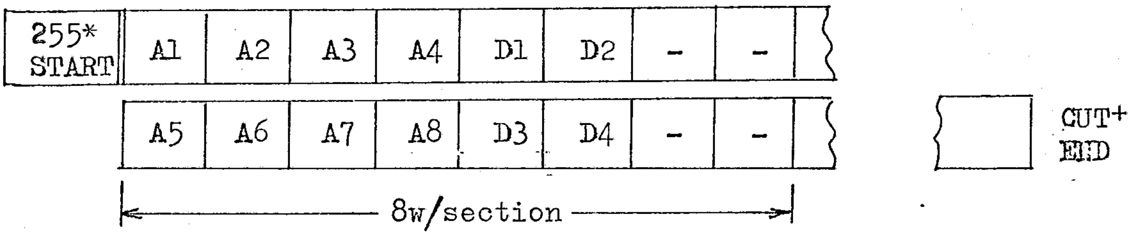
Note (1) A word of data recorded on this tape will be written at an address of the memory as specified above.
(2) Data should be represented by between 0* and 254* (not 255*).
(3) START and END should be spaced by 255w independently of the number of words of data actually used.

<u>Tape B</u> For reading the data in the RAM, in arbitrary order.



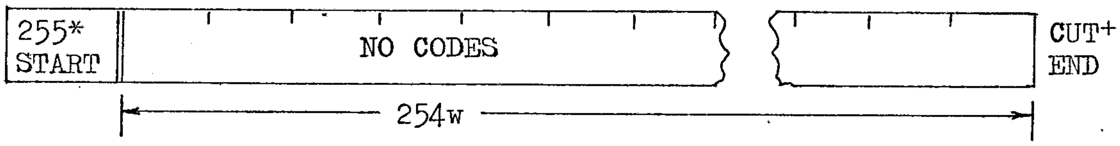
Note (1) Data in the memory will be read in the order of addresses specified by this tape. The same data can be read repeatedly.
(2) An address should be represented by a number between 2* and 244*.
(3) The length of the tape is not limited.

<u>Tape C</u> For reading data in the RAM in a particular order, and mixing other data in the output.



Note (1) A_n represents an address from which a word of data is read.
(2) D_n represents a word of data which should go directly to the output, after A_n to A_{n+3} have been read.
(3) A_n should be represented by a number between 2* and 244*; and D_n by a number between 0* and 244*.
(4) The length of the tape is not limited.

<u>Tape 0</u> For reading the memory written in the order of its addresses.



Note (1) Data in the memory will be read in the same order as the writing.
(2) If the tape is longer than 254w, the reading will be repeated in cycles.

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* A number with an asterisk shows a binary number which is indicated by a decimal number in this chapter for convenience.

\+ If the tape end is cut, the tape will stop automatically. However, code END (255*) is necessary for a tape for writing the data into the memory.

2.3 Circuit description

Tape control circuit for the tape-reader

Fig. 4 shows the circuits relevant to the tape-reader control (the circuits supplied with the standard model of the tape-reader are not shown).

The tape reader has a set of opto-electronic sensors, and generates a positive-going signal at the terminals on CN103, when there is a hole on each of the tape tracks. 8 data-tracks and one tape-feed-hole signal are available.

The tape-reader motor and clutch solenoid are activated separately by a combination of manual and electronic switches. Switch SW-FSB has three positions: F for forward run of the motor, S for stop, and B for backward run of the motor. At B-position, both the motor and clutch are activated by the switch itself, but at F-position, only the motor is activated by the manual switch, and the clutch is activated by the electronic switch. The motor requires about 30 ms to reach its maximum speed, and therefore this has to be switched on before the clutch is operated, when a high speed is required.

The circuits shown in the bottom part of Fig. 4 have been prepared for:-

(1) the continuous running of a tape, which is started by a manual switch, and stops by the tape-end code, '255', which is punched on the tape, automatically;

(2) the step-by-step movement of a tape, when a read-command signal is given to the circuit;

(3) the waveform shaping of the tape-feed-hole signal, and the read-command signal, which are required for this circuit and the RAM.

The FF (flip-flop), 00/1-6, controls the clutch of the tape-reader. The negative-going signal applied to 00/2 makes a tape run, and that applied to 00/5 stops the tape. The start signal is given from either BD31/22 or BD31/29. The stop signal is given from either the shaped feed-hole signal (through 121(2)) or the '255' signal (through 00/8-11 and 7492). For the latter, the '255' signal is given twice indicating the start and end of a tape, but the circuit detects the 'end' only to stop the tape. This selection is carried out by a 1/2 divider (92). Each 00/8-13, 121(1) and 121(2) is a pulse shaper by which a constant pulse width is obtained independently of that of the input signal.

In Fig. 4, a relay connected to CN103/17 and 18 is prepared for operating the tape reader with BD2. See its text for the details of its operations. When this relay is not activated, 121(2)/5 is connected to BD30/29.

Fig. 5 shows the timing diagram of the tape-reader control circuit (WRITE MODE only is shown).

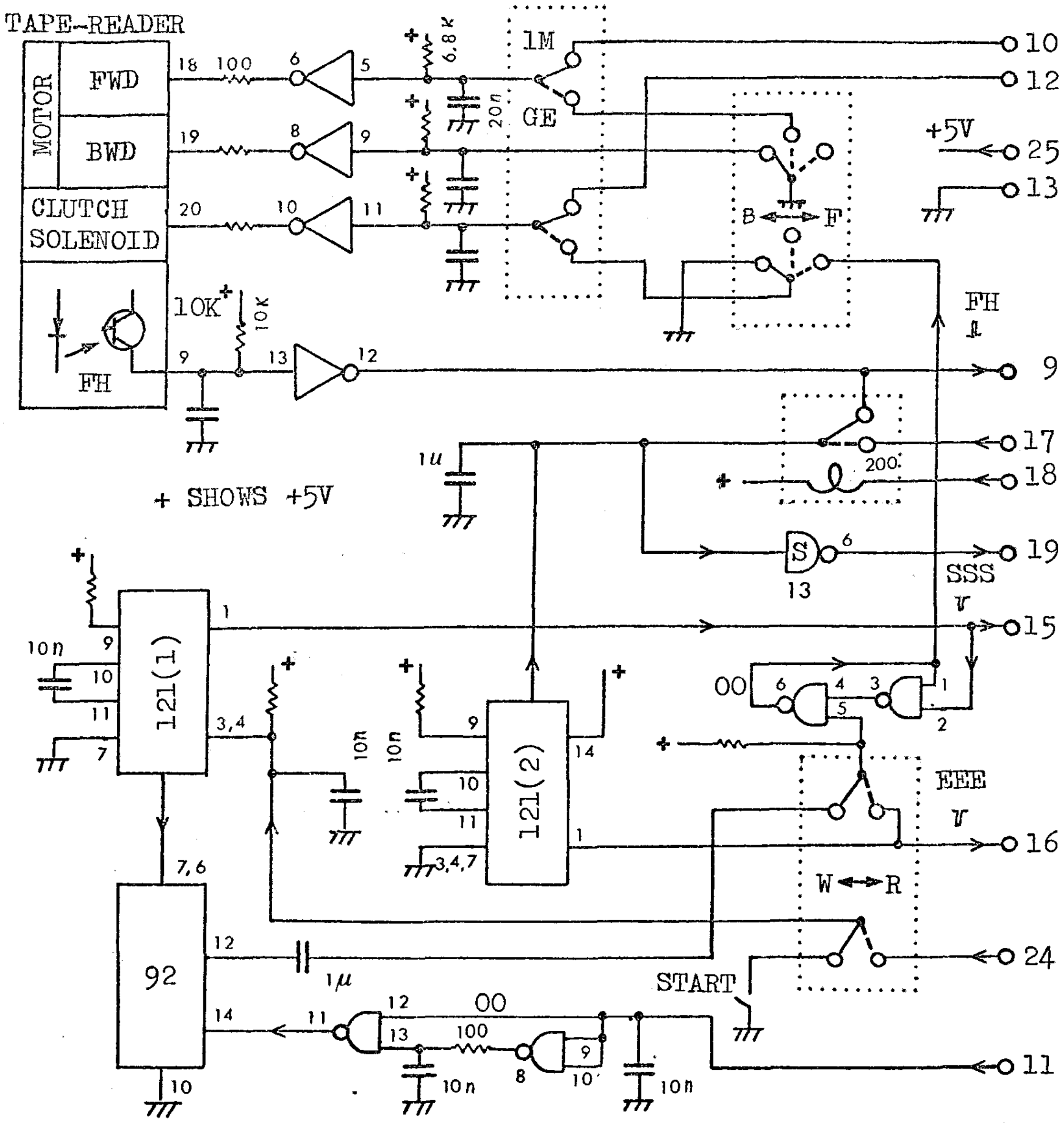


Fig. 4   Tape control circuit for the tape-reader.

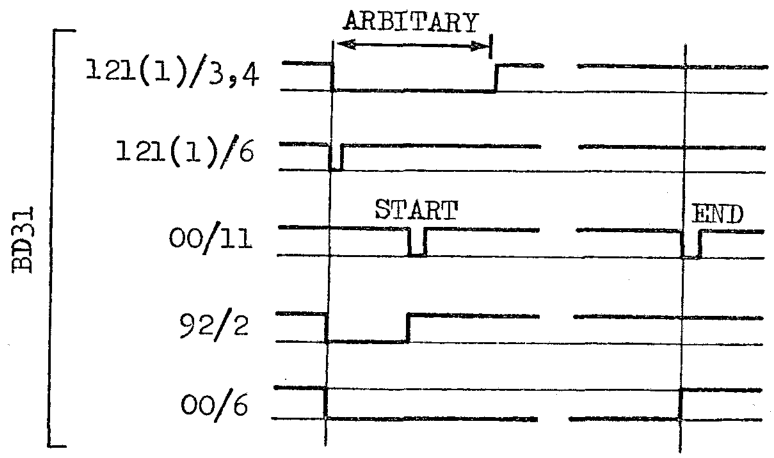


Fig. 5   Timing diagram of the circuit shown in Fig. 4.
Tape control in its write mode only is shown.

Memory and its associated circuits

Fig. 6 shows the circuit diagram of the RAM and its associated parts, and Figs. 7 and 8 show its timing diagram.

The RAM consists of two units of MM5269, each of which is a 256 × 4 bit MOS static random access memory with three-state output. It has four control terminals, LATCH (pin 17), OE(18), $\overline{\text{CE}}$(19) and WE(20), to each of these a signal in a different timing is required.

For WRITE, signal 'EEE' (see the previous chapter) is directly applied to the LATCH. The same signal is passed through a delay circuit (04/8-11), and its output, which is delayed by about 13/us, is applied to $\overline{\text{CE}}$. Another timing pulse is generated by 04/6 and 00/3 (the start of the pulse coincides with the start of pulse EEE, and its end coincides with the end of pulse $\overline{\text{CE}}$), and this is applied to WE. OE is kept in the low state by one of the manual switches.

For READ, signal EEE is again applied to LATCH. The output of the delay circuit is again applied to CE. The output of 04/6 is applied to OE, this time. OE is controlled by either one of the manual switches or the programmed switch, through 00/9,10.

The switching of all the data channels is carried out by 4 sets of three-state bus-buffer gates, 74126s. The same type of gates are built in the RAM.

For the sequential-code generator, 93(1) and (2) are used so that BINARY CODE 0 to 255 are obtained.

For the meteorological-input-data programme, a simple 1/8 divider consisting of 93(3) is used at the present. This can be programmed in a more complex mode if necessary. This controls the switching of ADR mode and PAS mode alternately which results in ALT mode.

For detecting '255' code on an input tape, a multiple input NAND gate, 30, is used. The output of this gate, inverted by 04/2 is used for resetting all the 93(1), (2) and (3).

The signal SSS is used for the clock only when the system is in WRITE MODE. This signal is generated by delaying the signal EEE. Each pulse of the SSS appears about 3 ms before the next pulse of EEE. This arrangement is important for this application, since a word on the second input tape should be sampled after the switching of ALT mode has been completed. Otherwise, the order of words in the output around the time of the switching will be disturbed. For example, the correct output

D(n-2), D(n-1) : MD(n), MD(n-1) ....

in Fig. 8 will become

D(n-1), D(n) : MD(n), MD(n-1) ....

where D(n) represents the nth word on the second tape, MD(n) represents the nth word written in the RAM and read in ADR mode, and : represents the instant of the switching.

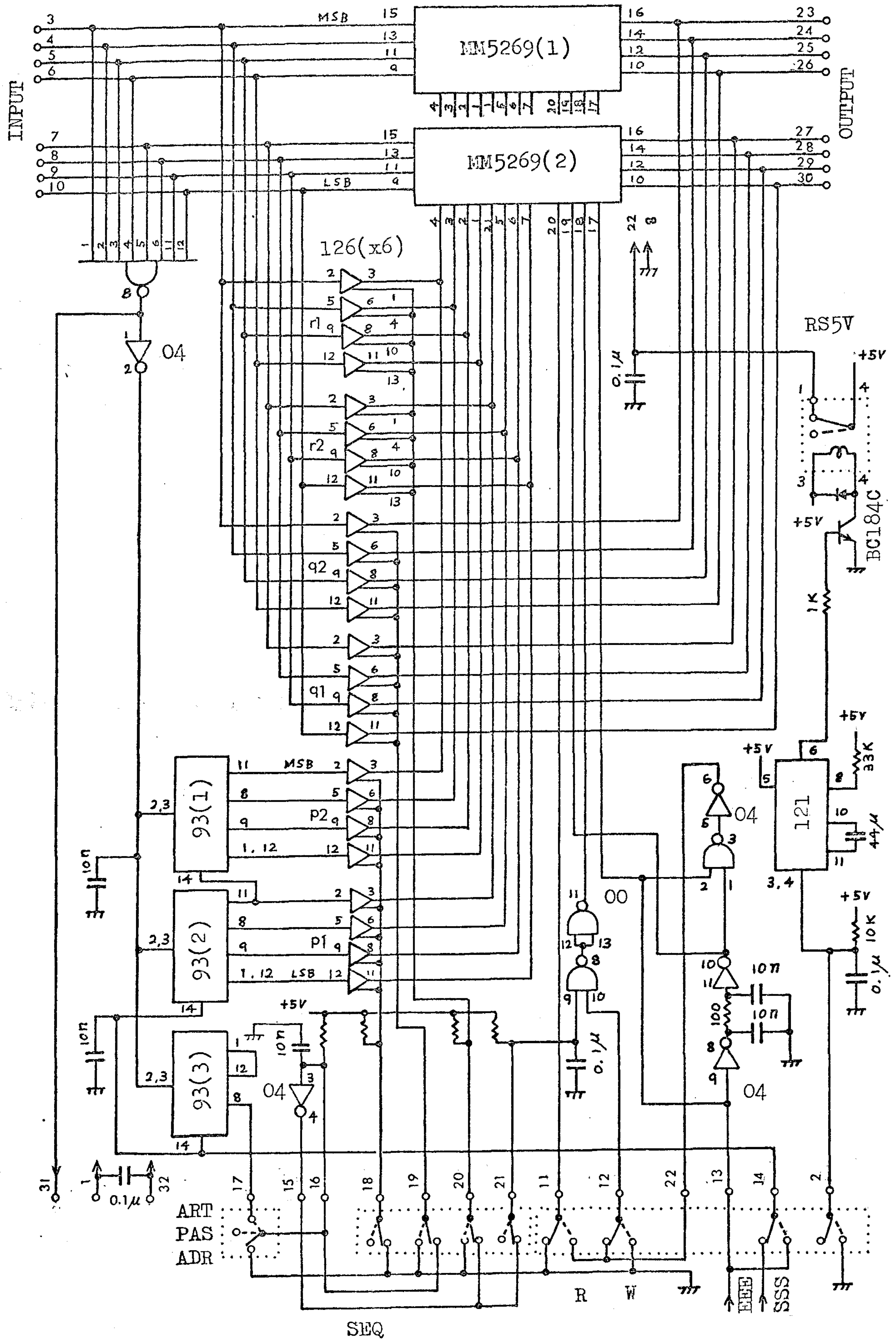


Fig. 6 Memory and its associated circuits, BD32.

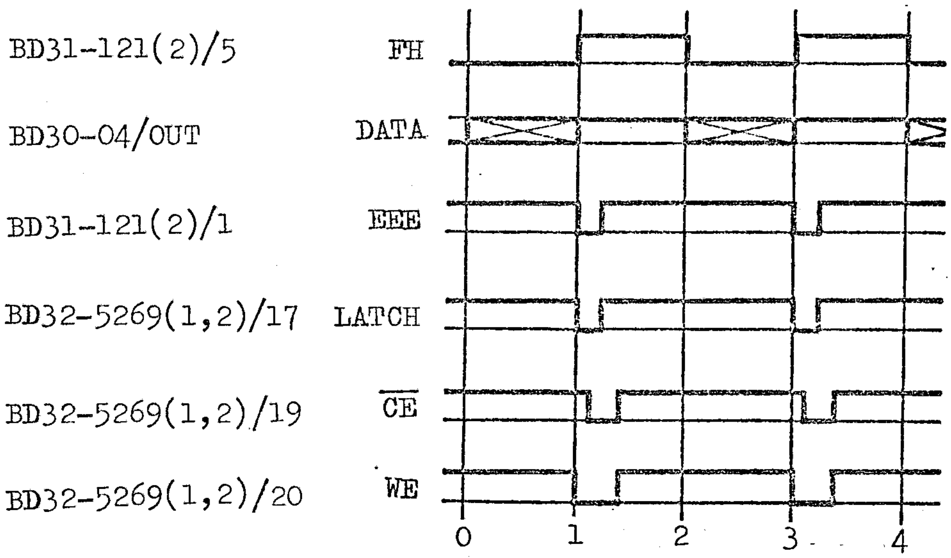


Fig. 7 Timing diagram of the circuit shown in Fig. 6 (write mode).

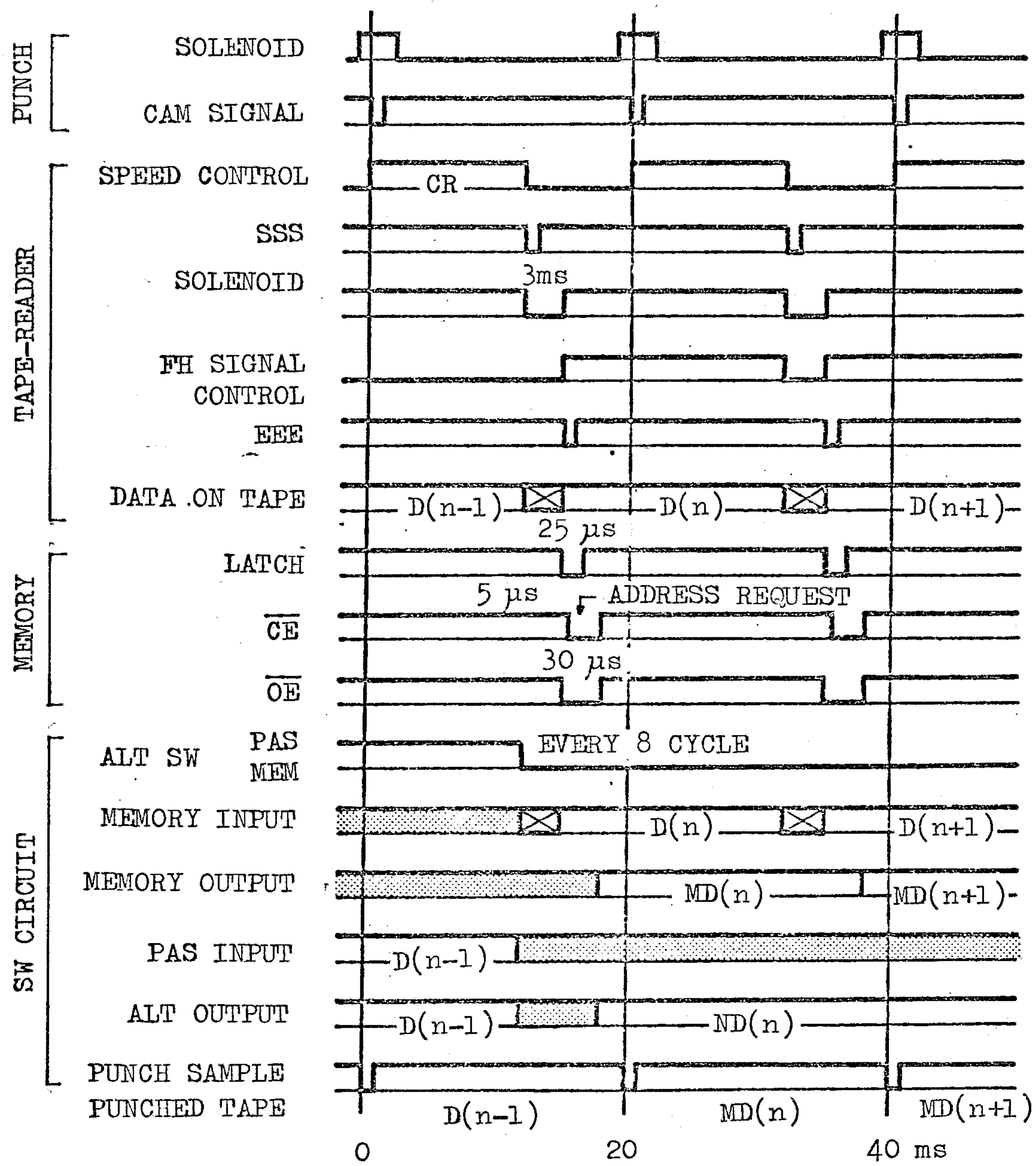


Fig. 8 Timing diagram of the circuit shown in Fig. 6 (read mode).

2.4 Physical arrangement

Fig. 9 shows the physical arrangement of the circuit shown in Fig. 6. IC sockets are mounted on a standard circuit board, and pins are wired on the rear of the board. Fig. 10 shows the connections of BD32 and other circuits.

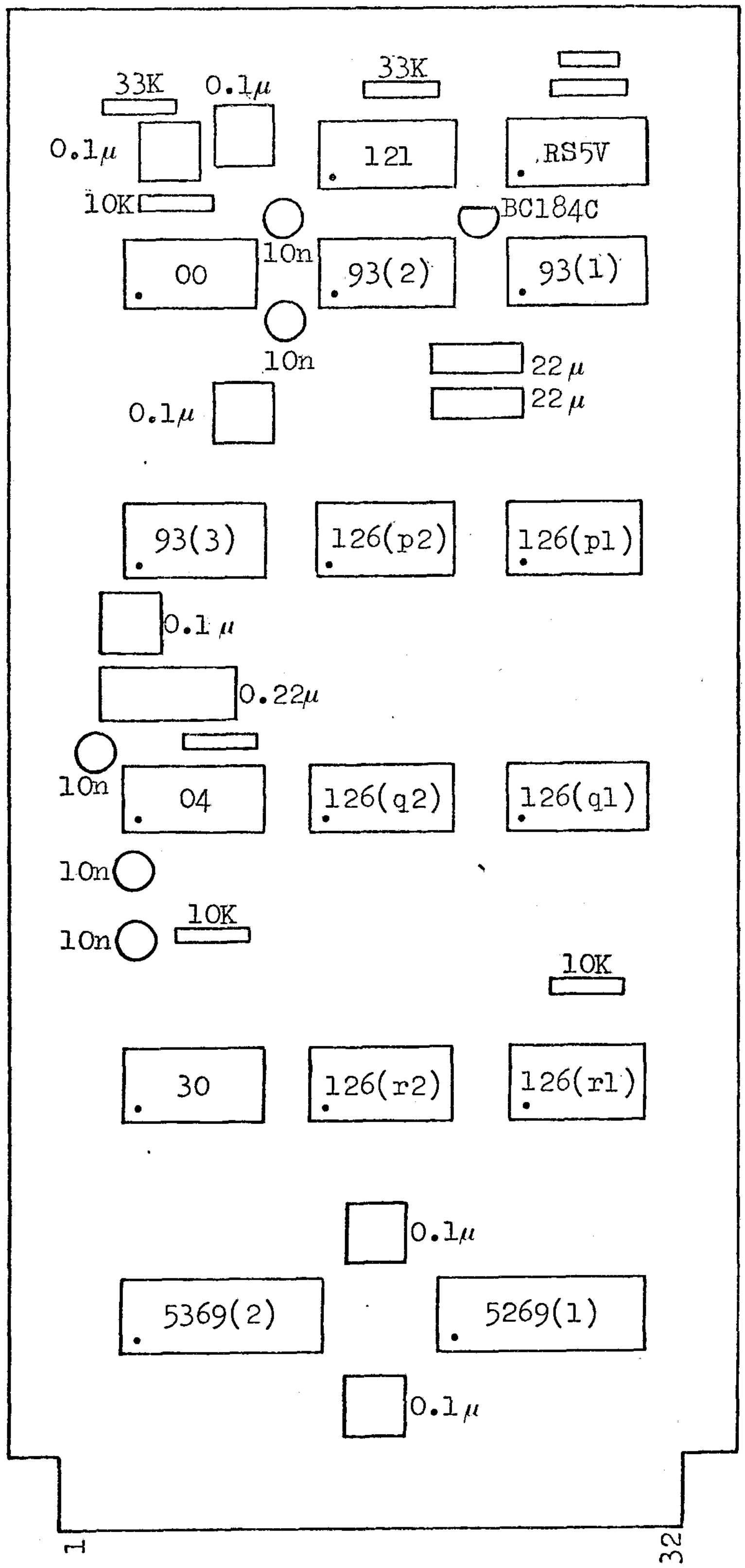


Fig. 9 Arrangement of the components on BD32.

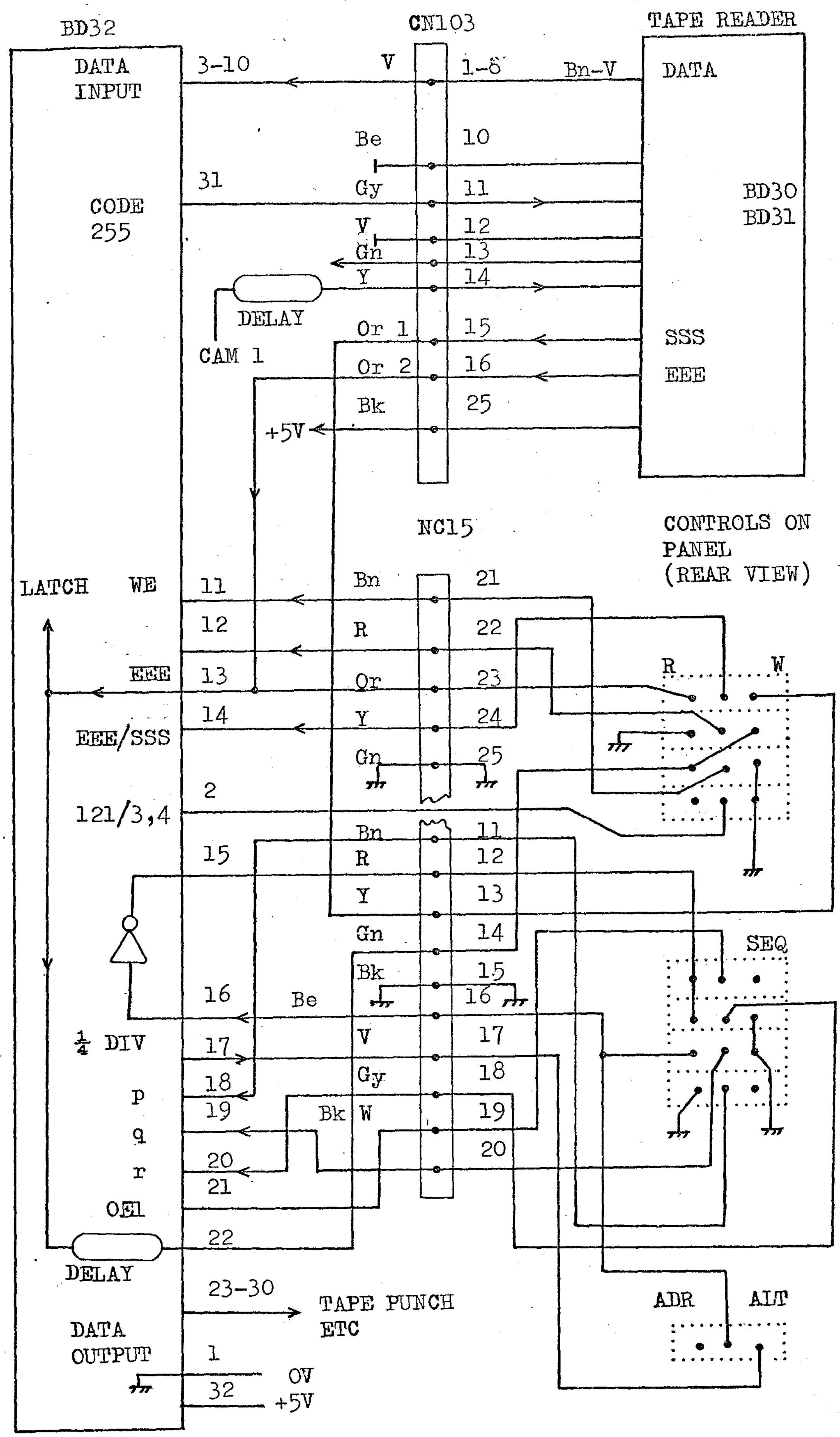


Fig. 10 Connections of BD32 and other circuits.

2.5 Test of the data editing unit

The performance of the data editing unit can be tested simply by using three test tapes. The formats of the tapes, and their correct outputs are described in this section:

Tape RAM-DATA-TEST For testing the write/read function of the RAM.

255* START	-	-	254*	253*	252*

2*	1*	0*	255* END

257 words

Use this tape in WRITE MODE, and read the data in the memory in SEQ MODE (see section 2.2). The correct output is:

-	-	-	253*	252*

2*	1*	0*

257w

Tape RAM-ALT-TEST For testing ALT MODE (see section 2.2).

255* START	0*	1*	2*	3*	0*	1*	-	-
	4*	5*	6*	7*	2*	3*	-	-
	253*	253*	254*	254*	126*	127*	-	-

CUT[+] END

Write the RAM by using tape RAM-DATA-TEST, and confirm it by SEQ MODE. Then apply tape RAM-ALT-TEST. The correct output is:

1*	0*	0*	254*	253*	0*	1*	-	-
	253*	252*	251*	250*	2*	3*	-	-
	4*	3*	2*	2*	126*	127*	-	-

Tape RAM-ADR-TEST For testing the ADR MODE (see section 2.2).

255*	0*	1*	2*	3*	4*

253*	254*	-	-	255*

258w

Write the RAM by using tape RAM-DATA-TEST, and check it by SEQ MODE. Then read the RAM in ADR MODE by using tape RAM-ADR-TEST. The correct output is:

1*	-	-	254*	253*	252*

2*	1*	0*	-	1*

2.6 Example of a data editing operation

An example of a data editing operation by using the formats of Tape A and Tape C (§2.2) is demonstrated.

1 Suppose there is an isobar map with 133 grids. The value on each grid is read manually (or digitized) and recorded on a tape through a keyboard. The order of reading can be chosen for the operator's convenience, e.g. from the top-left to bottom-right. The format of Tape A should be applied to this case. Then the contents of the tape will be as shown in Table 1.

2 Suppose we want to combine four pressure values read at 4 adjacent grids which form a square a-b-c-d as shown in Fig. 11. Such a square can be formed all over the map, but take one square as an example. Since the order of such 4 values, P_a, P_b, P_c, P_d in Table 1 is fixed, the memory addresses in which these values are written are also fixed, e.g. for the first square, address 48, 49, 51, 52.

3 If we also want to combine these 4 values with the values representing the latitude, ϕ, and the mean water depth of the square, h. The combined set will appear

$$P_a,\ P_b,\ P_c,\ P_d,\ \phi,\ h,\ -,\ -$$

where - represent a blank.

4 The format for Tape C should be applied to this case. Memory address 48, 19, 51, 52 should be used for A_1, A_2, A_3, A_4 of this format (see §2.2), and the values of ϕ and h (e.g. ϕ = 139, h = 51) should be used for D_1 and D_2. Then the actual tape will be

048, 049, 051, 052, 139, 051, 000, 000

The same procedure can be applied to all the squares on the map. The contents of a completed tape will be as shown in Table 2.

5 If this tape is processed by the data editing unit, after the contents of Table 1 are written into the memory, the output of the unit will produce a series of numbers as shown in Table 3. Note, a tape in the format of Tape C can be used repeatedly for all the maps in the same form, while the contents shown in Table 1 have to be changed for each map. The processing speed is limited by the tape punch (75 ch/s), and it will take about 20s to complete Table 3.

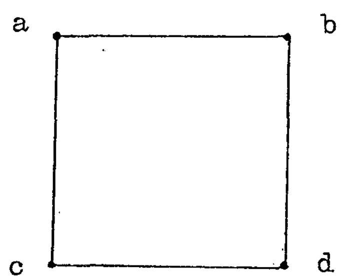


Fig. 11 A square formed by four adjacent grids.

Table 1 Example of contents of Tape A.
Atmpspheric pressure values on an isobar map.

START p_a p_b p_c p_d

000	255	000	000	045	035	021	051	045	020	010	009	078	079	063	059	055	076	079	059
049	048	060	101	091	082	075	074	072	092	087	077	071	085	099	109	106	103	100	095
090	110	104	095	096	100	114	128	118	115	116	119	113	107	127	122	122	124	121	140
150	132	122	127	130	128	125	145	143	146	154	161	175	185	172	128	127	130	138	137
025	023	026	034	041	055	065	145	145	140	138	140	142	042	059	057	060	070	080	094
160	162	162	167	172	174	074	075	079	084	092	101	112	177	183	189	192	099	100	105
112	122	131	191	201	206	211	126	131	137	204	211	154	147	150	154	057	000	000	000

END

Table 2 Example of contents of Tape C.

START A_a A_b A_c A_d ϕ h – –

000	255	048	049	061	062	139	051	000	000	035	036	048	049	137	080	000	000	023	024
035	036	134	098	000	000	011	012	023	024	132	114	000	000	134	092	011	012	130	149
000	000	049	050	062	063	140	075	000	000	036	037	049	050	138	110	000	000	024	025
036	037	136	130	000	000	012	013	024	025	134	131	000	000	002	003	012	013	132	128
000	000	050	051	063	064	142	075	000	000	037	038	050	051	140	114	000	000	025	026
037	038	137	126	000	000	013	014	025	026	135	127	000	000	003	004	013	014	133	206
000	000	052	053	001	002	144	026	000	000	039	040	032	033	141	024	000	000	027	028
039	040	139	010	000	000	011	000	011	028	137	190	000	000	001	002	015	000	135	174
000	000	033	034	000	001	145	000	000	000	032	001	001	000	001	000	000	000	012	009
040	041	141	203	000	000	030	001	000	001	001	001	000	000	000	001	001	000	000	001
000	000	034	035	003	000	001	041	000	000	003	042	034	035	001	035	000	000	009	010
041	032	139	033	000	000	001	002	001	000	000	033	000	000	035	000	000	001	001	032
000	000	032	035	033	032	003	032	000	000	010	001	032	033	129	035	000	000	000	001
010	001	000	003	000	000	032	041	001	002	003	033	000	000	043	040	040	041	129	032
000	000	031	032	043	044	147	019	000	000	007	008	040	041	149	063	000	000	014	011
027	008	002	009	000	000	033	032	002	003	002	000	000	000	044	041	057	058	151	016
000	000	000	009	001	095	011	035	000	000	028	029	041	042	151	060	000	000	015	000
008	009	020	035	000	000	002	003	034	035	001	032	000	000	001	002	002	003	140	006
000	000	042	043	052	117	155	014	000	000	093	094	106	107	153	039	000	000	015	001
029	030	150	027	000	000	046	047	059	060	135	155	000	000	034	035	047	048	135	030
000	000	043	040	033	034	137	021	000	000	030	031	043	044	155	031	000	000	017	016
030	031	152	038	000	000	047	048	050	061	137	096	000	000	052	063	132	133	163	022
000	000	034	035	042	053	166	019	000	000	044	109	118	119	157	032	000	000	095	096
044	109	158	029	000	000	018	019	031	032	155	033	000	000	010	011	022	019	130	160
000	000	041	042	035	040	162	020	000	000	047	048	057	058	146	156	000	000	034	035
011	048	144	154	000	000	021	022	034	035	141	031	000	000	048	049	058	059	148	069
000	000	099	100	112	113	145	076	000	000	086	087	099	100	142	074	000	000	100	101
113	114	146	064	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000

END

Table 3 Example of the edited result. The contents of Tapes A and C are combined.

START p_a p_b p_c p_d ϕ h – –

000	255	116	119	127	130	139	051	000	000	103	100	116	119	137	080	000	000	083	076
103	100	134	098	000	000	070	063	083	076	132	114	000	000	057	045	070	063	130	149
000	000	119	113	130	128	140	075	000	000	100	095	119	113	138	110	000	000	075	074
100	095	136	130	000	000	063	059	075	074	134	131	000	000	045	036	063	059	132	128
000	000	113	107	128	125	142	076	000	000	095	090	113	107	140	114	000	000	074	072
095	090	137	126	000	000	059	056	074	072	135	127	000	000	036	031	059	055	133	206
000	000	127	123	145	143	144	020	000	000	110	104	127	123	141	088	000	000	092	087
110	104	139	078	000	000	076	070	092	087	127	190	000	000	051	045	076	070	135	238
000	000	123	122	143	145	145	080	000	000	104	099	123	122	111	110	000	000	087	077
104	099	141	067	000	000	072	055	087	077	139	215	000	000	128	125	140	142	144	059
000	000	122	124	145	154	147	041	000	000	099	096	122	124	145	055	000	000	077	071
099	096	143	055	000	000	055	040	077	071	140	225	000	000	124	131	154	161	149	045
000	000	095	100	124	131	147	044	000	000	071	085	096	100	145	039	000	000	040	040
071	085	142	097	000	000	131	140	161	175	151	039	000	000	000	050	121	140	149	036
000	000	085	090	036	050	147	019	000	000	042	050	010	011	149	063	000	000	025	021
042	050	145	077	000	000	140	150	175	185	154	024	000	000	050	128	140	150	151	016
000	000	132	128	145	145	139	115	000	000	050	057	011	011	151	060	000	000	023	026
050	057	148	053	000	000	091	083	106	103	133	115	000	000	128	127	145	140	149	079
000	000	015	015	036	041	155	014	000	000	057	063	015	020	153	039	000	000	010	034
057	063	150	027	000	000	054	051	132	128	136	155	000	000	106	103	151	116	135	094
000	000	084	092	041	048	157	021	000	000	051	002	000	000	139	031	000	000	034	041
063	086	152	038	000	000	051	052	128	127	137	070	000	000	131	137	150	134	153	022
000	000	048	038	131	137	034	003	000	000	028	037	048	058	157	032	000	000	079	080
092	101	158	029	000	000	041	055	070	080	155	033	000	000	078	070	091	083	139	164
000	000	101	112	122	131	152	020	000	000	177	183	191	201	146	156	000	000	160	162
161	183	144	154	000	000	145	145	160	034	002	011	000	000	183	189	137	142	148	095
000	000	152	153	183	189	145	076	000	000	143	140	152	153	142	010	000	000	103	167
189	192	145	054	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000	000

END

3. COMPUTING UNIT

The computing unit has been designed for computing a set of meteorological input data, before it is fed into the main computation circuit which carries out the dynamic computation. The computing unit consists of several sub-units:-

Six input channels, each having an 8-bit memory and DAC;

Two-dimensional gradient unit, TDG, which functions

$$x = (a + b - c - d)/K \qquad y = (a - b + c - d)/K$$

Vector-rotation unit, VUR, which functions

$$x = X \cos \delta + Y \sin \delta, \; y = X \sin \delta + Y \cos \delta;$$

Vector-sum unit, VSU, which functions

$$z = \sqrt{x^2 + y^2}$$

Three multiplying units, M1U, M2U, M3U;

Adding unit, ADU; and

8-bit ADC.

The combination of the units, and constants within each unit are changeable so that different equations in a similar form can be computed.

3.1 Typical equations to be computed

A typical set of equations,

$$\xi_x h_a = \left(\frac{\Delta x}{\rho g}\right)\left[(1/\sin^2\phi)\left(\frac{k}{4\rho_a \omega_E}\right)\beta^2 (\mathbb{P}_x \sin\delta + \mathbb{P}_y \cos\delta)\sqrt{\mathbb{P}_x^2 + \mathbb{P}_y^2} + h_a \mathbb{P}_x\right] \tag{1}$$

$$\xi_y h_a = \left(\frac{\Delta y}{\rho g}\right)\left[(1/\sin^2\phi)\ \frac{k}{4\rho_a \omega_E}\ \beta^2 (\mathbb{P}_x \cos\delta - \mathbb{P}_y \sin\delta)\sqrt{\mathbb{P}_x^2 + \mathbb{P}_y^2} + h_a \mathbb{P}_y\right] \tag{2}$$

$$\mathbb{P}_x = (p_a + p_b - p_c - p_d)/2(2\Delta x) \tag{3}$$

$$\mathbb{P}_y = (p_a - p_b + p_c - p_d)/2(2\Delta y) \tag{4}$$

is used for explaining the uses of the computing unit, throughout this chapter.

In these equations,

$$p_a,\ p_b,\ p_c,\ p_d,\ \phi,\ h_a \tag{5}$$

are variables, and

$$\left(\frac{\Delta x}{\rho g}\right),\ \left(\frac{\Delta y}{\rho g}\right),\ \left(\frac{k}{4\rho_a \omega^2_E}\right),\ \beta,\ \delta \tag{6}$$

are constants within a certain storm case. The values finally required for each grid of the model are ξ_x and ξ_y. These are obtained by dividing equations (2) and (3) by h, where $h \doteq h_a$. These dividing operations are carried out by two circuits contained in each grid of the model. (The reason why the dividing operations by h are left to the very last stage of the process is explained in another paper).

3.2 Maximum values of parameters

The maximum values of variables in the above equations should be estimated, before the flow chart is designed.

Pressure gradient

From the definition of $\mathbb{P}_x$ and $\mathbb{P}_y$,

$$|\mathbb{P}_x|_{max} = |\mathbb{P}_y|_{max} = \sqrt{\mathbb{P}_x^2 + \mathbb{P}_y^2} \equiv \mathbb{P}$$

$$|\mathbb{P}|_{max} = 10^3 \text{ gr cm}^{-2}\text{s}^{-2} \tag{7}$$

has been chosen as the maximum value. This value is equivalent to the pressure gradient of 10 mb/100 km which produces approximately 45 m/s of wind speed in the North Sea, according to statistical data. An extreme wind speed in the North Sea for a recurrence period of 50 years is approximately 40 m/s (hourly-mean value at the height of 10 m above the sea level) (Shellard, 1974).

Note the maximum value of $|\mathbb{P}|$ is independent of the absolute values of p_a, p_b, p_c and p_d.

Water depth

The present model covers the sea around the British Isles whose water depth is less than 200 m. Considering instrumental convenience for coding the values,

$$|h_a|_{max} = 2.54 \times 10^4 \text{ cm} \tag{8}$$

has been chosen as the maximum value.

Latitude

The lowest latitude involved in the present model is $\phi = 50^\circ$, therefore

$$|1/\sin^2\phi|_{max} = 1.70 \tag{9}$$

has been chosen. However, the code system which has been chosen for instrumental convenience can cover

below $1/\sin^2\phi = 2.54$

or up to $\phi = 38.86^\circ$

3.3 Example of the computation scheme

Since the construction of circuit board BD2 is versatile, it is possible to make several different flow charts even for the same set of equations.

Fig. 12 shows an example of the computation scheme for Equations (1) to (4). This illustrates the process of computing the equations by using the same symbols as those in the original equations.

The six variables (Equation 5) are fed into the board through the input tape. Five constants (Equation 6) are set on the board for each storm case. In practice, it is not often necessary to change them.

The intermediate output is recorded on a tape to be kept permanently, so that this can be fed into the grids of the model, through the Input Memory, at any time. The memory can store the whole of the data until its power supply is switched off.

Fig. 13 shows the same scheme as Fig. 12, but for determining the range of values involved. Since only the maximum value of each variable is of interest, for this purpose, all the equations are shown in a greatly simplified form. At the same time, 'voltages' and their coefficients which are required for the calibration of the circuit board, are introduced in this chart. Their details are explained in the following paragraph.

The introduced factors are as follows:-

$$F_p = \mathbb{P}/E_p \tag{9}$$

where E_p is the output of TDG, VRU and VSU. Note the operations with VRU and VSU do not involve the change of dimensions of data.

$$F_1 = \mathbb{P}^2/E_{MIAB} \tag{10}$$

where E_{MIAB} is the output of M1U

$$F_\phi = (1/\sin^2\phi)/E_\phi \tag{11}$$

where E_ϕ is the voltage representing $(1/\sin^2\phi)$.

$$F_h = h_a/E_h \tag{12}$$

where E_h is the voltage representing

E_p, E_{MIAB}, E_ϕ and E_h can be chosen arbitrarily within instrumental limitations. However, all these values have chosen as 5V, for the simplicity of practical operations. For example,

$$F_p = \mathbb{P}/5 \quad \text{gr cm}^{-2}\text{s}^{-2}\text{V}^{-1}$$

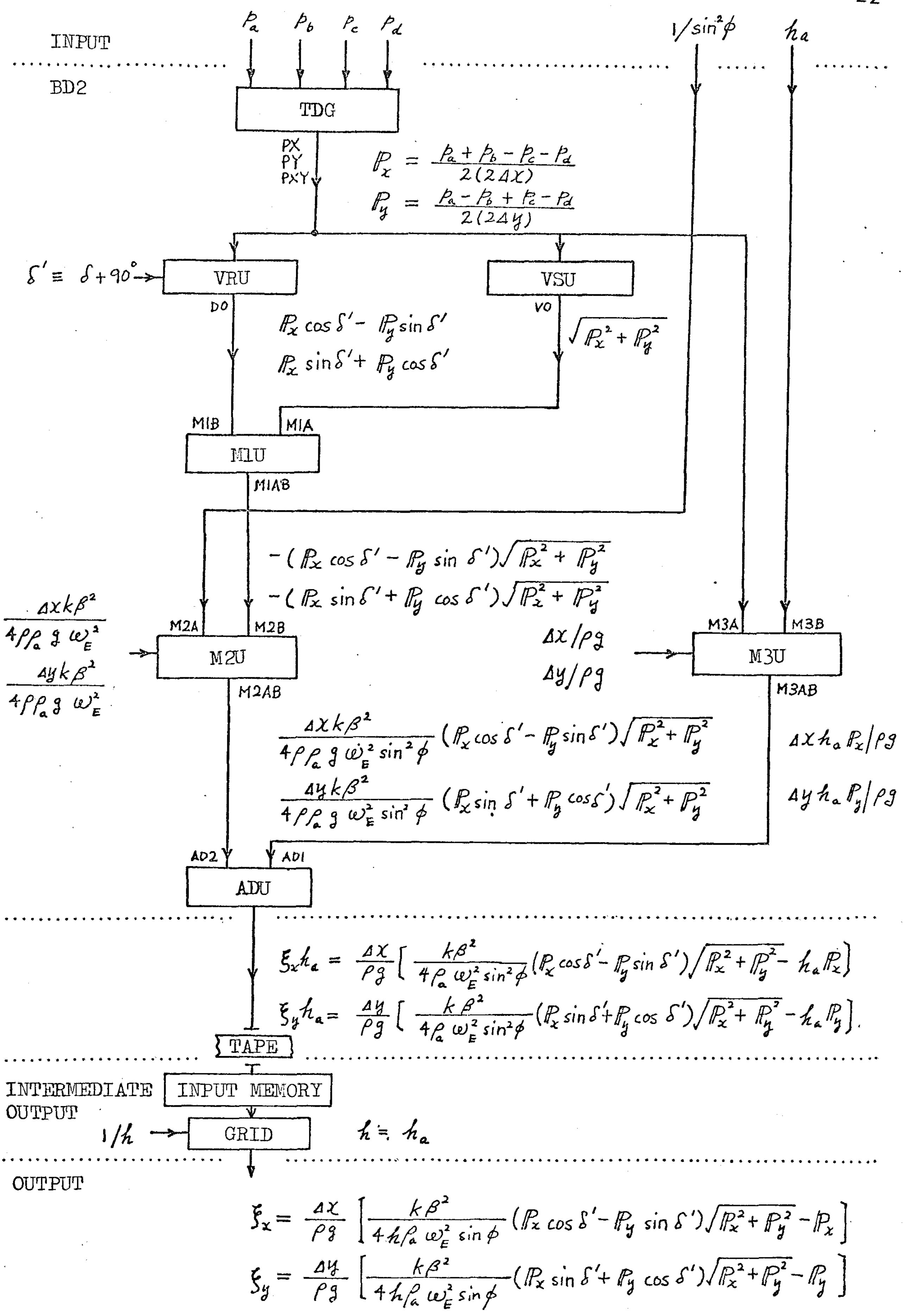


Fig. 12 Example of a computation scheme with the sub-computing units.

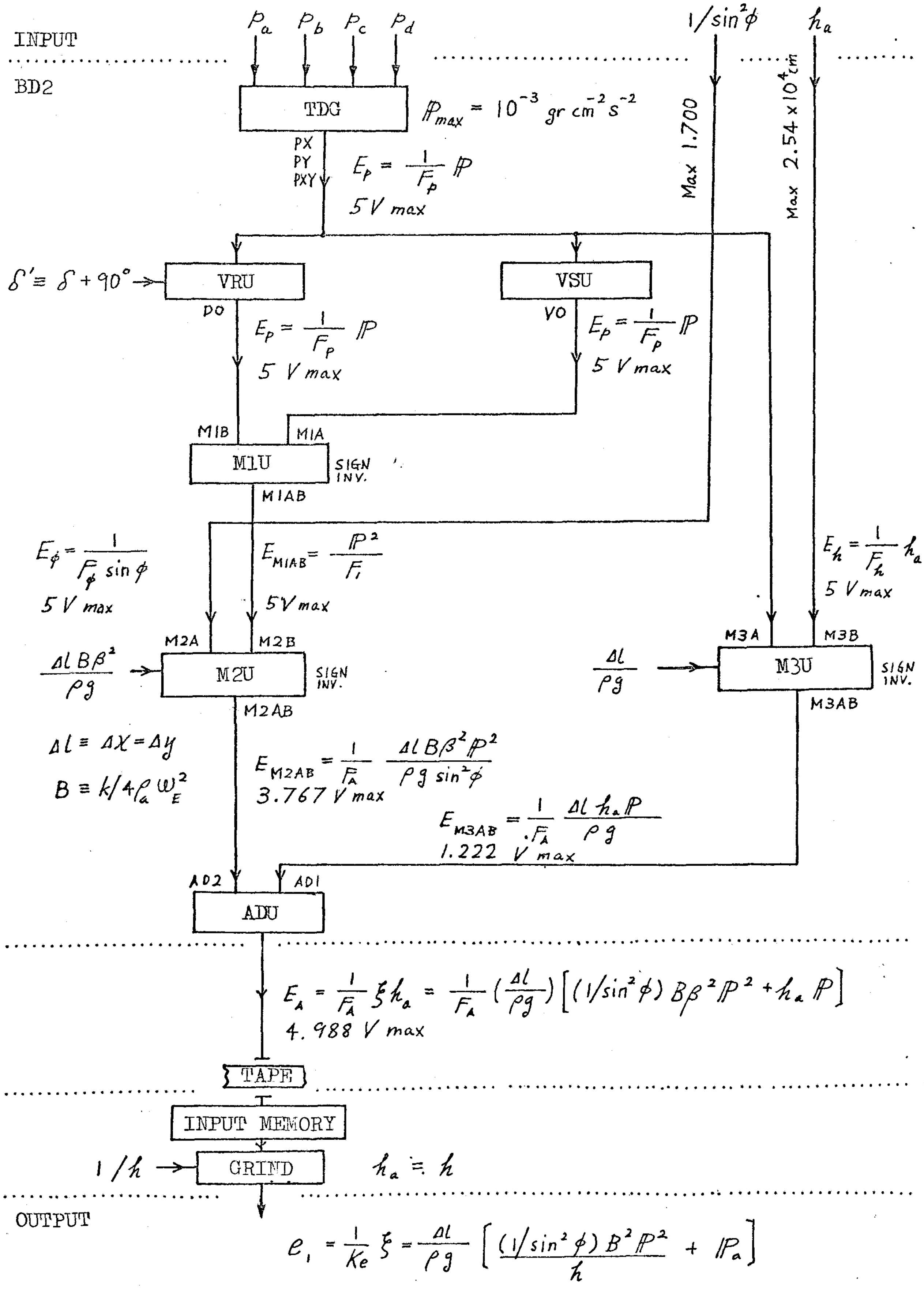


Fig. 13 Example of the scaling in the computation scheme shown in Fig. 12.

E_{M2AB} (the output of M2U) and E_{M3AB} (the output of M3U) are added by ADU, and this produces E_A. If ADU has a unit gain, the factor for all these three voltages should be the same, and this is represented by F_A. Therefore,

$$F_A\ E_{M2AB} = \left(\frac{\Delta l}{\rho g}\right)\ (1/\sin^2\phi) B\beta^2 \mathbb{P}^2 \tag{13}$$

$$F_A\ E_{M3AB} = \left(\frac{\Delta l}{\rho g}\right)\ (1/\sin^2\phi) h_a \mathbb{P} \tag{14}$$

$$F_A\ E_A = \xi h_a = \left(\frac{\Delta l}{\rho g}\right)\left((1/\sin^2\phi)B\ \beta^2 \mathbb{P}^2 + h_a \mathbb{P}\right) \tag{15}$$

The value of F_A can be chosen arbitrarily in principle. In practice, however, this should be chosen so that the maximum value of ξh_a is recorded on the tape as close to its full scale (245*) as possible, but not exceeding it.

The output of ADU (in the hydrodynamic terms)

$$F_A\ E_A = \xi h_a = \left(\frac{\Delta l}{\rho g}\right)\left((1/\sin^2\phi)B\ \beta^2 \mathbb{P}^2 + h_a \mathbb{P}\right) \tag{16}$$

becomes a maximum when $\mathbb{P}$ and h_a are maximum at the same time. Taking their maximums as described in page 20, and taking $|E_A|\max = 5V$, F_A is determined by equation (16). The value of F_A determined in this way is not necessarily a simple number. A nearest simple number is

$$F_A : 1.1 \times 10^5 \quad cm^2\,V^{-1} \tag{17}$$

When F_A is fixed to this value, the values of related terms become as follows:-

$$\left.\begin{array}{lrll}
 & |\xi h_a|_{max} & = 548.716 \times 10^3 & cm^2 \\
 & |E_A|_{max} & = 4.9883 & V \\
 & |1/\sin^2\phi| & = 1.70 & \\
\text{for} & |h_a|_{max} & = 2.54 \times 10^4 & cm \\
 & |\mathbb{P}|_{max} & = 10^{-3} & gr\ cm^{-2}s^{-2} \\
\text{also} & & & \\
 & \xi & = 21.603 & cm \\
 & e_1 & = 4.3206 \times 10^{-3} & V \\
 & \text{for } K_e & = 5 \times 10^3 & cm\ V^{-1}
\end{array}\right\} \tag{18}$$

The value of $|E_A|$ is very near to the scale of 5V, i.e. the dynamic range of a tape whose full scale is 254 is almost fully utilized.

Note, the conditions which make ξh_a or E_A maximum are not necessarily equal to the conditions which make ξ or e_1 maximum, since h_a and h are involved. For example,

$$\xi h_a = 419.640 \times 10^3 \text{ cm}^2$$

$$E_A = 3.8149 \quad \text{V}$$

$$1/\sin^2\phi = 1.70$$

for

$$h_a = 10^3 \quad \text{cm}$$

$$\mathcal{P} = 10^{-3} \quad \text{gr cm}^{-2}\text{s}^{-2}$$

also

$$\xi = 418.64 \quad \text{cm}$$

$$e_1 = 81.928 \times 10^{-3} \quad \text{V}$$

$$\text{for } K_e = 5 \times 10^{-3} \quad \text{cm V}^{-1}$$

ξ and e_1 in the latter is far greater than in the former.

A summary of the main factors is given as follows:-

$$\left.\begin{aligned} F_p &= 2.000 \times 10^{-3} && \text{gr cm}^{-2}\text{s}^{-2}\text{V}^{-1} \\ F_\phi &= 3.400 \times 10^{-1} && \text{V}^{-1} \\ F_h &= 5.000 \times 10^{-1} && \text{cm V}^{-1} \\ F_A &= 1.100 \times 10^{5} && \text{cm}^2\text{V}^{-1} \\ K_e &= 5 \times 10^3 && \text{cm V}^{-1} \end{aligned}\right\} \qquad (19)$$

The practical procedure of setting these factors on a circuit board BD2 is described in section 3.6.

Both the two input voltages, $E_{M2A}(=E_pE_p)$ and $E_{M2B}(=E_\phi)$, of MU2 become maximum (both 5V) when $\mathcal{P} = 10$ (CGS units) and $1/\sin^2\phi = 1.70$. Applying the above mentioned value of F_A, the output voltage of MU2 is obtained from equation (14),

$$E_{M2AB} = \frac{1}{F_A}\left(\frac{\Delta l}{\rho g}\right)(1/\sin^2\phi)B\ \beta^2\mathcal{P}^2 \qquad (20)$$

$$= 3.7668 \quad \text{V}$$

Similarly, both the two input voltages, E_{M3A} and E_{M3B}, of MU3 become maximum (both 5V) when $\mathcal{P} = 10$ (CGS units) and $h_a = 2.45 \times 10^4$ cm. The output voltage of MU3 is obtained from equation (15),

$$E_{M3AB} = \frac{1}{F_A}\left(\frac{\Delta l}{\rho g}\right)h_a\mathcal{P} \qquad (21)$$

$$= 1.2215 \quad \text{V}$$

3.4 Circuit description

Fig. 14 (a, b, c) shows the circuit of the computing unit. Fig. 15 shows its timing diagram.

Input data represented by 8-bit binary words enters into the computing unit, together with a synchronization signal, FH (the top-left of Fig. 14). The data is fed into 6 sets of data holders, a_1, a_2 ... h_1, h_2 (12 IC packages of 75). Each set of the data holders is activated sequentially by a timing circuit 155, so that each holder can hold one particular word at a time. After a set of 6 words have entered, the 6 words are held simultaneously until one cycle of operation (typically a few milli seconds) has been completed.

Each of the 6 words is converted into an analogue voltage, by 6 sets of DACs (425s) with their output circuits (747s). The channels of these voltages are indicated by a, b, c, d, ϕ, h in the right side of Fig. 14a and the left side of Fig. 14b.

The voltages, a, b, c, d, are permanently fed into circuit TDG (the top left of Fig. 14b) by which the differences of the 4 voltages are computed. The output of this circuit which represents the values of ϕ and h are fed into the rest of the computing sub units, VSU, VRU, M1U, M2U, M3U, and AD, in various combinations depending on the computation required.

The output of the computing sub units is digitized by a DAC (425), after it is passed through a scaling circuit. Other than the final output of the computation, the outputs from most stages of computation can be selected by selector TO and TL (Fig. 14c), and are digitized by the same DAC, for intermediate checking. The selector can also select a standard voltage for a calibration.

The synchronization between this computing unit and external units is carried out by a circuit consisting of 93, a part of 155, 13, 121 and 04.

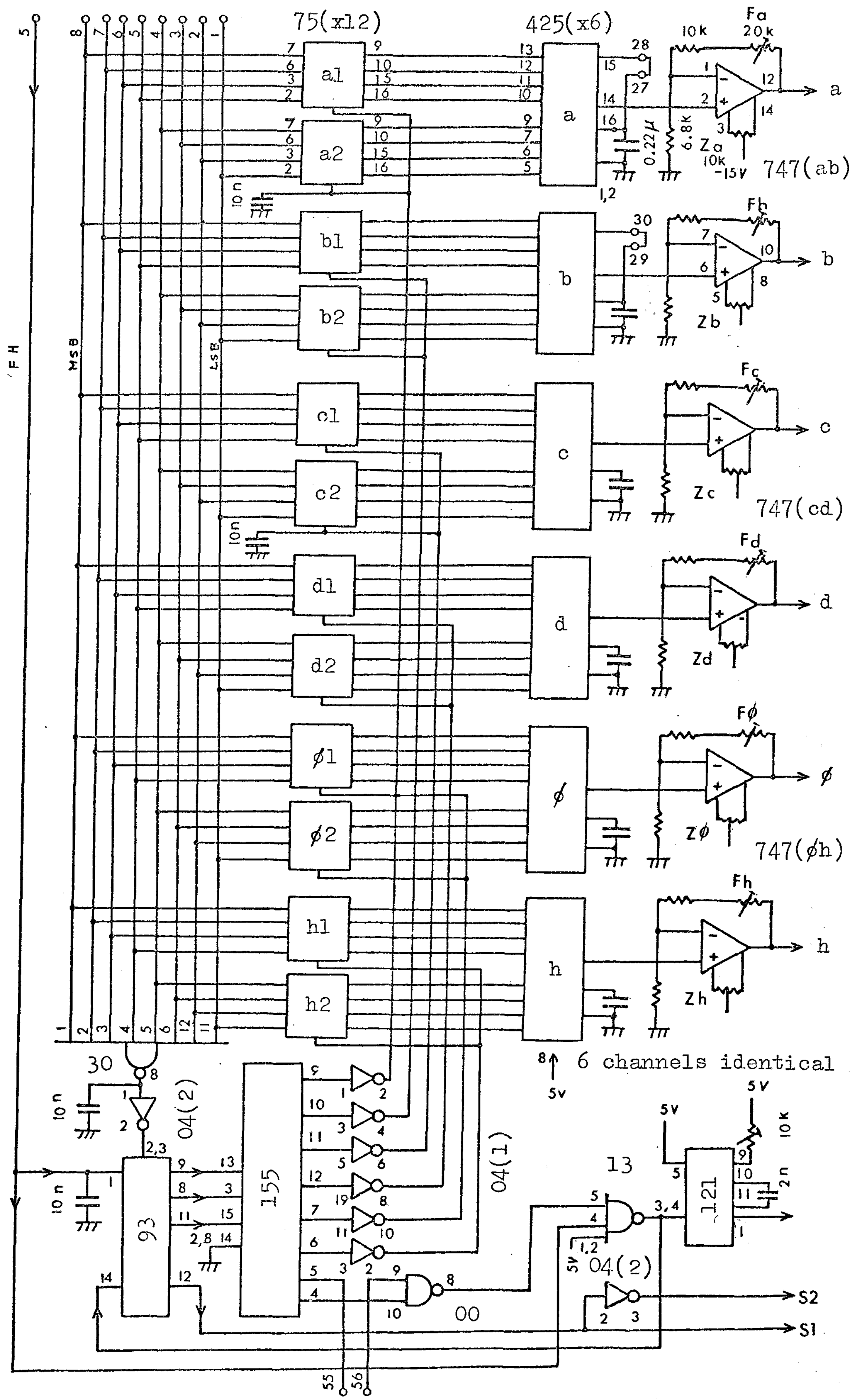


Fig. 14(a) Circuit diagram of computing circuit BD2. Continued to the following pages.

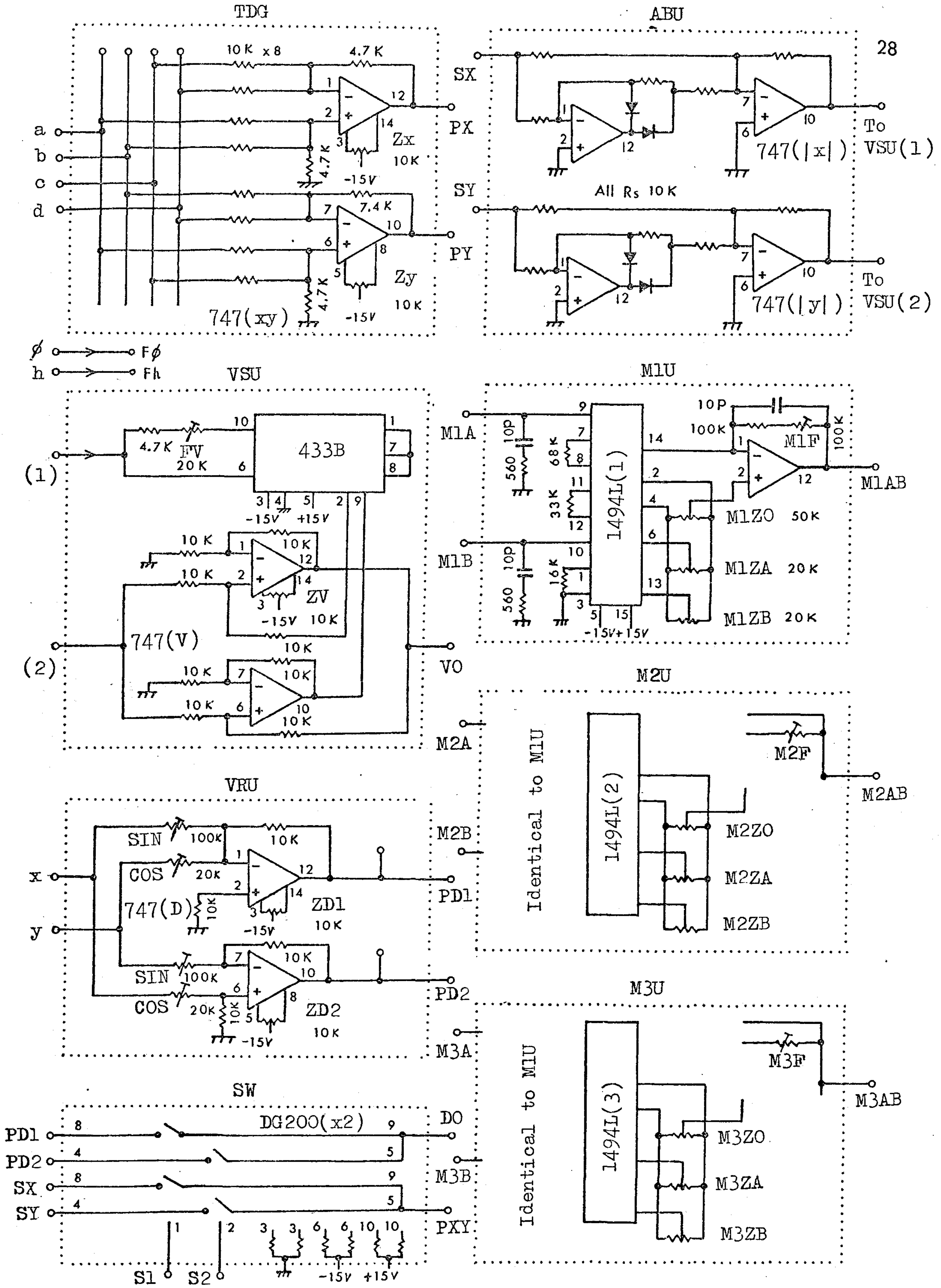


Fig. 14(b) Circuit diagram of computing circuit BD2.
Continued to the following page.

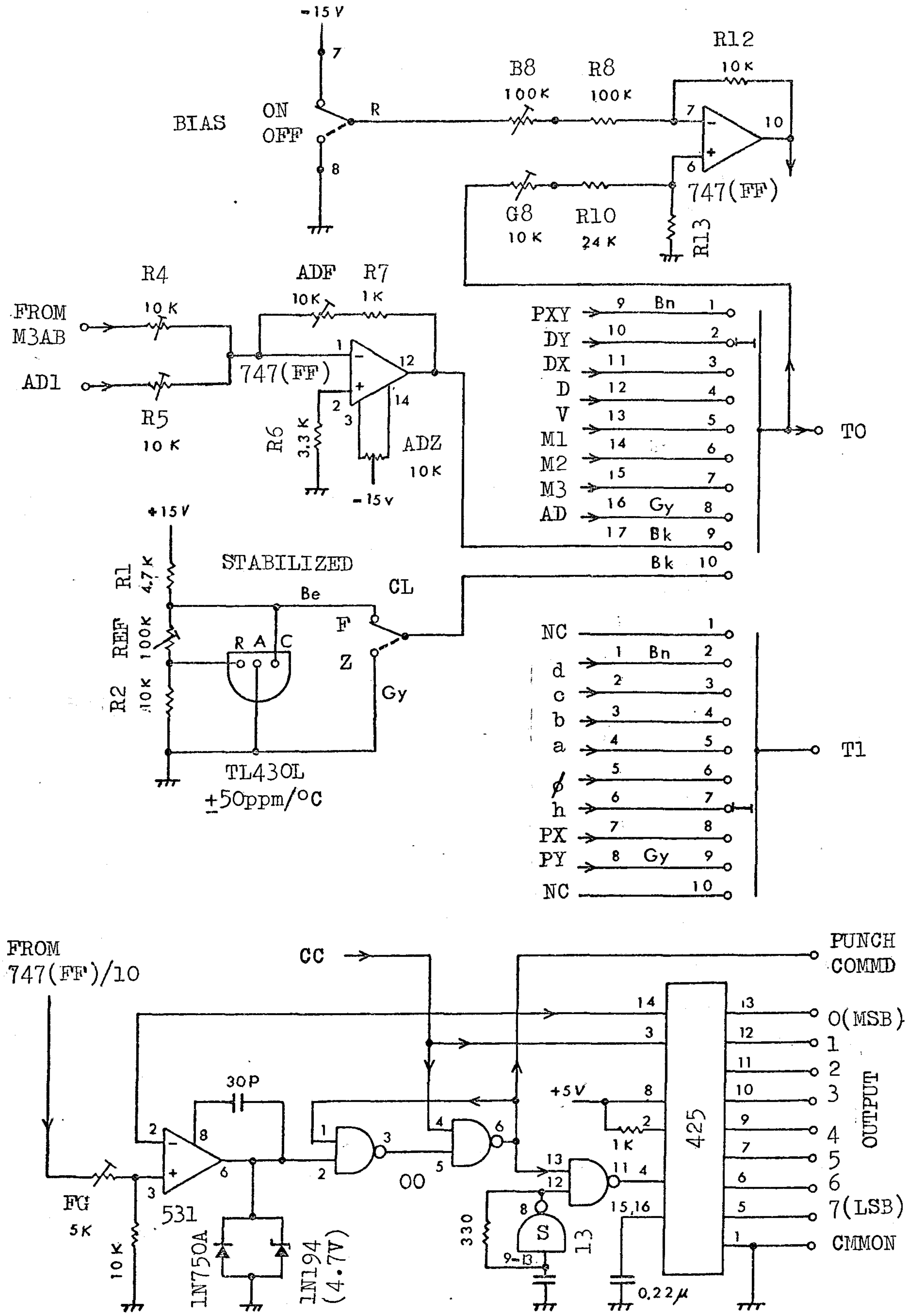


Fig. 14(c) Circuit diagram of computing circuit BD2.
Continued from the previous pages.

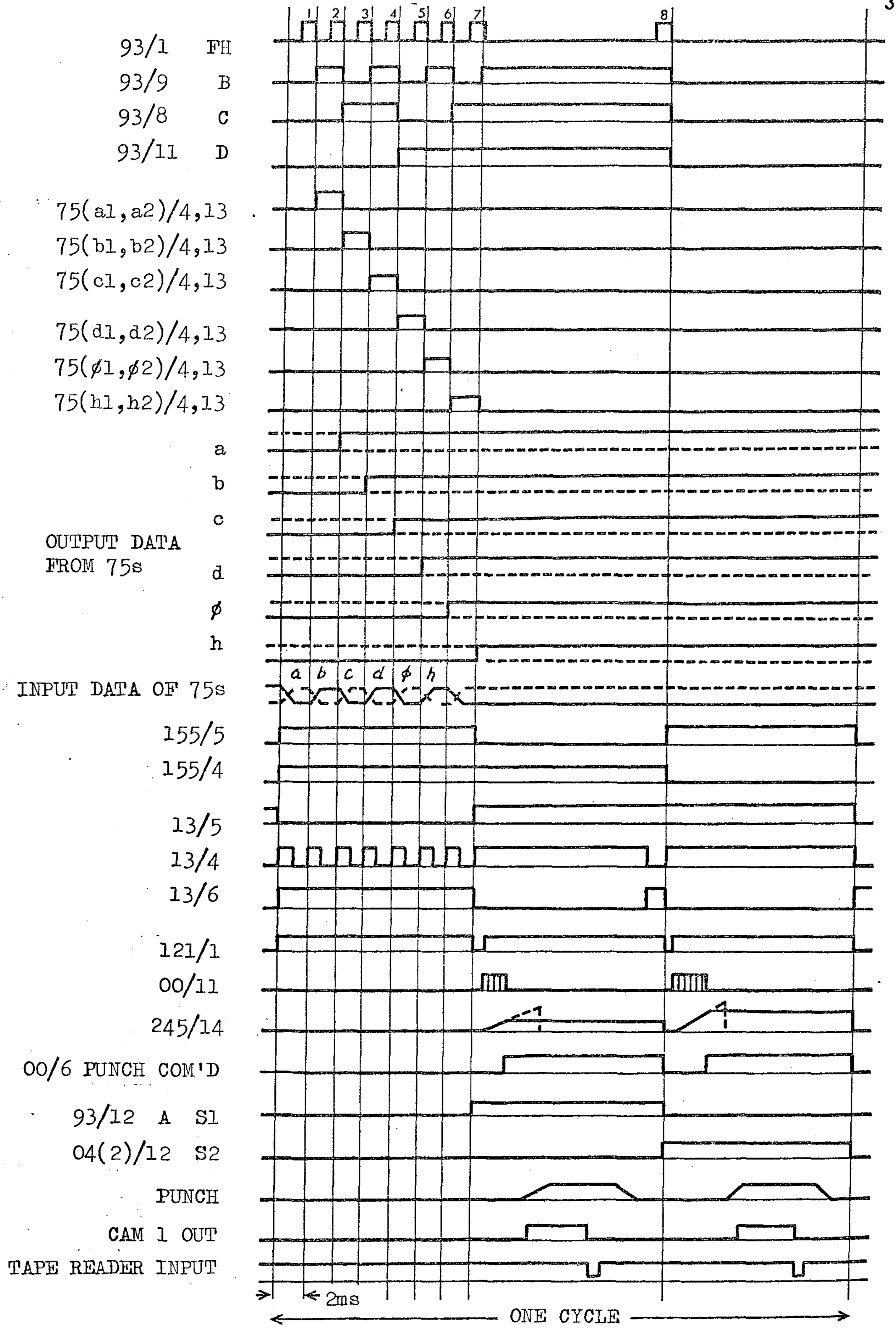


Fig. 15 Timing diagram of computing circuit BD2.

3.5 Physical arrangement

Fig. 16 shows the board on which all the components of the computing unit are mounted. Micro connectors have been used for jump wires by which the combinations of computing sub units can be changed. Semi fixed potentiometers have been colour-coded according to their functions.

Fig. 17 and Fig. 18 show the whole unit (BD2) contained in a case. This case also contains the vector plotting unit (BD33), and power supplies (+5V 1A and ±15V 0.2A). A heat sink for the power supplies has been mounted outside the case.

Control switches for both the computing unit and vector plotting unit are mounted on the front panel of the case. The outer dimensions of the case are 7.5 × 21 × 23 cm^3, and the weight of the whole system is 3.3 kgr.

Table 4 shows the pin connections related to BD2.

Table 4 Connections of BD2

Main cabinet internal wire colour		CN6	Cable wire colour	Met-Input-Data Proc. case
Bn	DATA INPUT	1	Bn	BD2/8 (MSB)
R		2	R	7
Or		3	Or	6
Y		4	Y	5
Gn		5	Gn	4
Be		6	Be	3
V		7	V	2
Gy		8	Gy	1 (LSB)
W		9	W	BD2/15 FH
-		10	Bk	-
Gy	DATA OUTPUT	11	Gn-D	BD2/47 (LSB)
V		12	P	46
Be		13	Be/R	45
Gn		14	Gn/R	53
Y		15	Y/R	52
Or		16	W/R	51
R		17	Bk/R	50
Bn		18	Bn/R	49 (RMS)
Gy/Gn		19	Y/Be	SG4 Be
Bn/Be		20	W/Be	" Gy
Gy/Bn		21	Bk/Be	" V
Common		22	Or/Be	Common
		23	Y/Gn	
		24	W/Gn	
		25	Or/Gn	

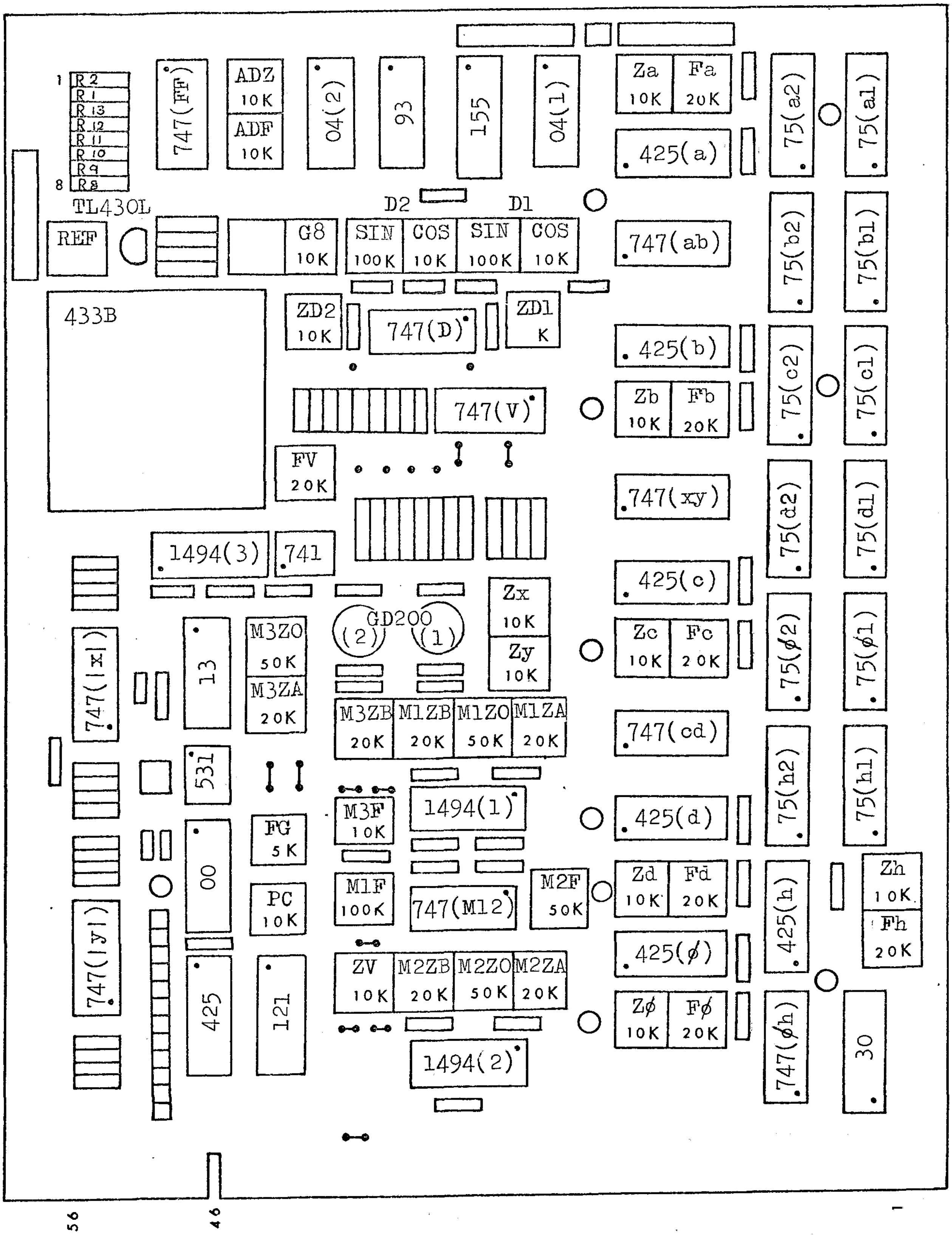


Fig. 16 Arrangement of the components on BD2.

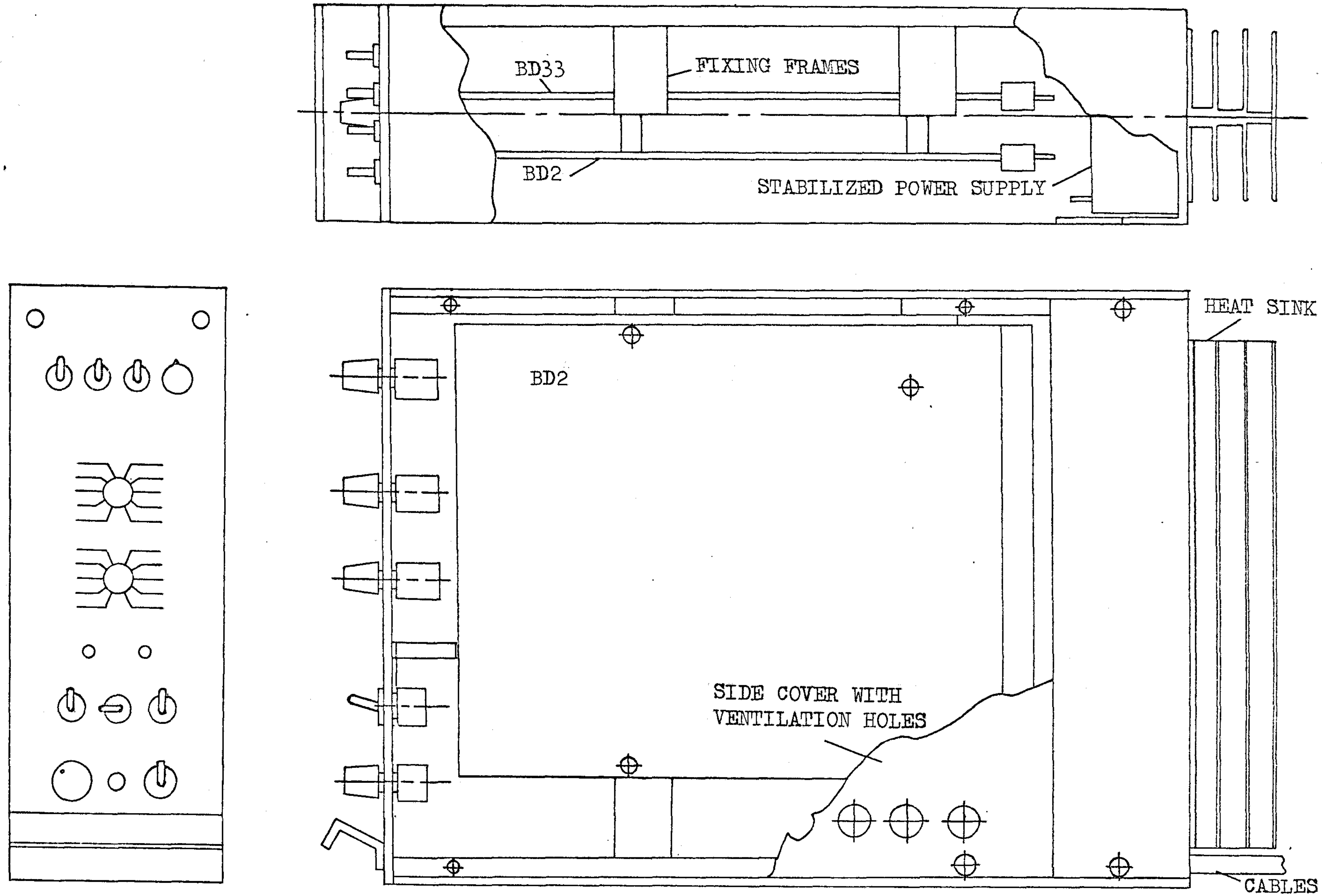
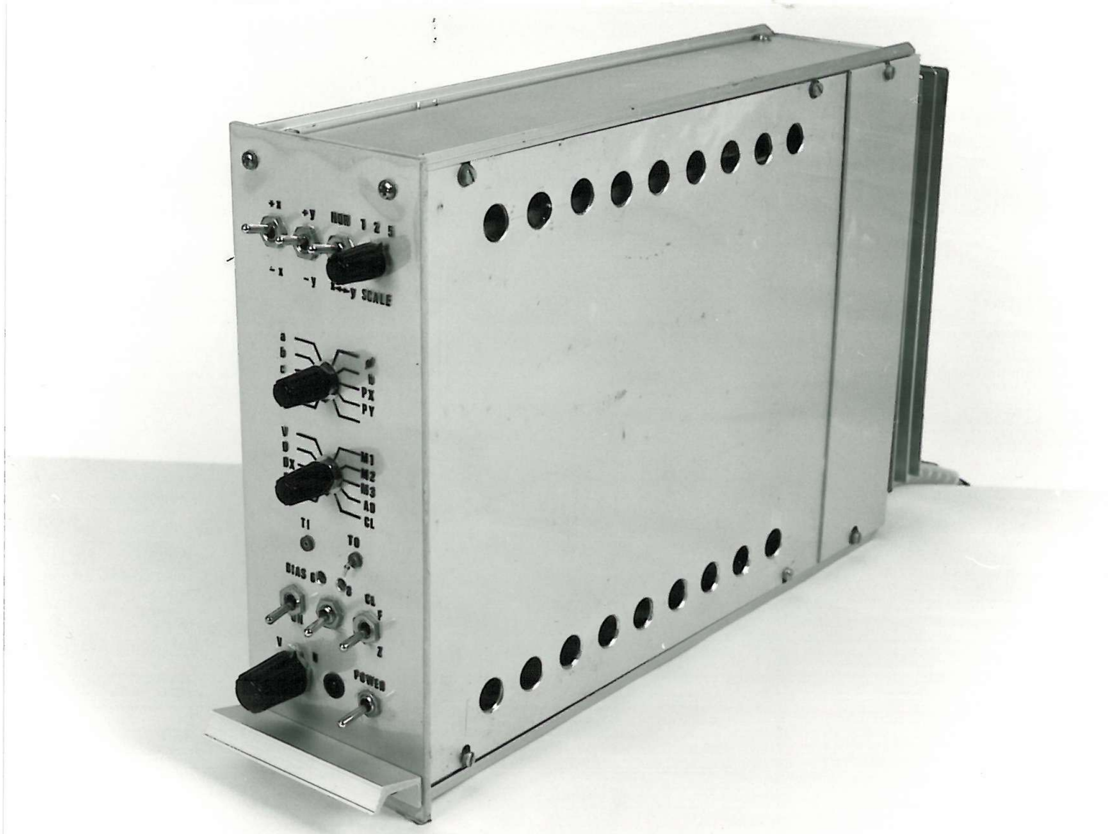


Fig. 17 Construction of the case containing BD2 and BD33.



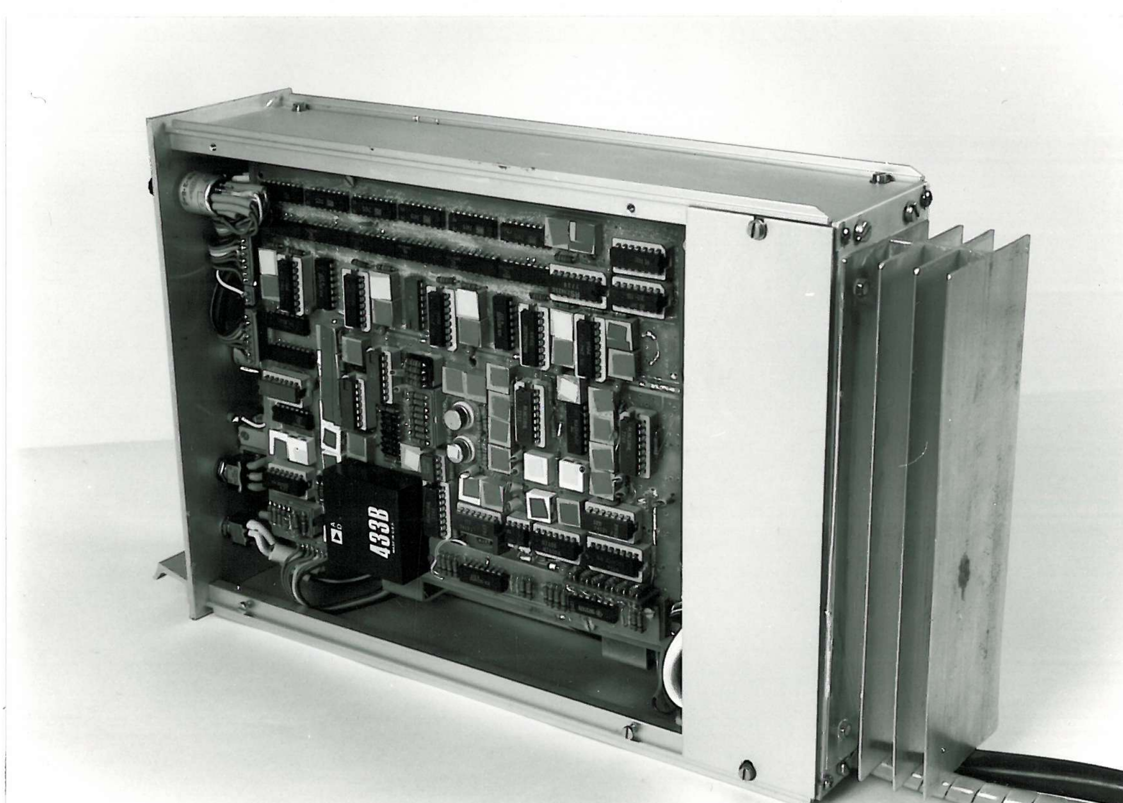


Fig. 18 Main part of the meteorological input data processing system.

3.6 Tests and adjustments

The full tests and adjustments of board BD2 are necessary only when this is assembled for the first time, or when some of its components are replaced. For a normal operation, the test by using test tape BD2TT-254/154-100/0 which takes only a few minutes will be enough to confirm the performance of the whole system.

When the values of some constants in the equations involved are altered, a few constant-setting potentiometers have to be adjusted, but these will not affect other settings.

Fig. 19 shows the locations of components relating to the tests and adjustments of BD2. After the adjustments, each component is sealed by a piece of PVC tape which is colour-coded as follows:-

Output-scale setting	(Green)
Zero setting	(Blue)
Full-scale setting	(Yellow)
Constant setting	(Red)

The full tests require the test tapes (see the following section) and the following instruments:-

Standard voltage source, 5.000V
4-digit digital voltmeter
Sine-wave voltage generator, 1 kHz, 5V approx., low output impedance

Cautions

Due to two CMOS devices contained in BD2, the following points should be noted:-

a When the power supplies of BD2 are off, no external voltage must be applied to terminals PXY, DO, SX, SY.

b When BD2 is operational, terminals PXY and DO must not be earthed.

3.6.1 Test tape formats

In order to test the computing circuit on board BD2, a set of test tapes have been prepared, as shown in Table 5. All the tapes are 8-track punched tapes, using the natural binary code. However, each binary figure is indicated by an equivalent decimal figure, throughout this chapter. For example, binary 1100 1000 by decimal 254.

Table 5 List of test tapes for BD2

Reference No.	Application
BD2TT-0	To set all the input channels to zero.
-200a	To set channel a to the full scale.
-200b	b
-200c	c
-200d	d
-170ϕ	ϕ
-254h	h
-100ϕVR	To test the variation of ϕ.
-100hVR	h.
-254/154-100/0	Quick checking of the whole system.

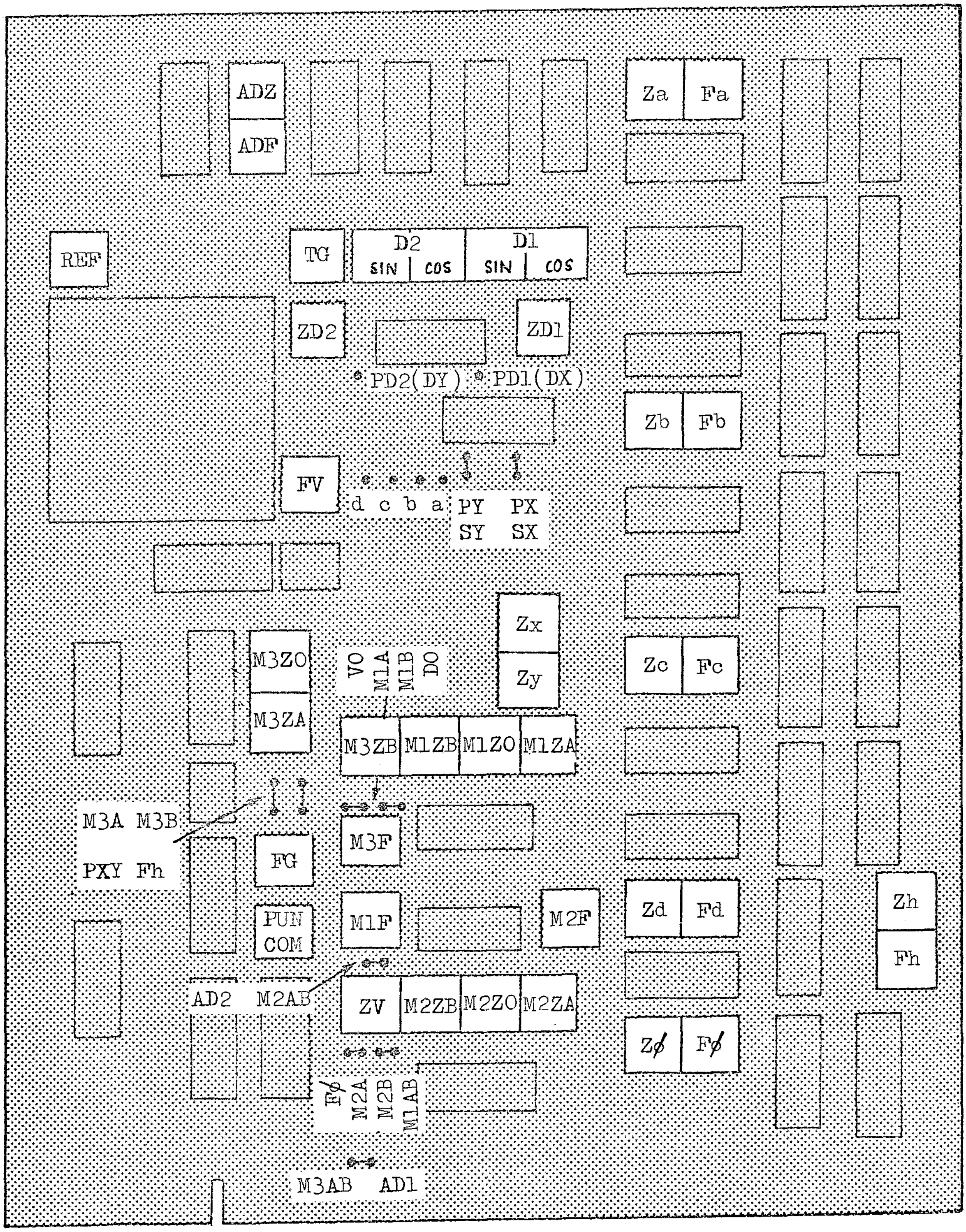


Fig. 19 Locations of controls on BD2.

Test tape BD2TT-0

This tape has no word, but has tape-feed holes only. The tape should be a few metres in length, or an endless form about 10 cm in diameter.

Test tapes BD2TT-200a to BD2TT-200d

Table 6 Format of the tapes

Ref. No.	START CODE	1 a	2 b	3 c	4 d	5 ϕ	6 h	7 –	8 –
BD2TT-200a	255	200	000	000	000	000	000	000	000
b	255	000	200	000	000	000	000	000	000
c	255	000	000	200	000	000	000	000	000
d	255	000	000	000	200	000	000	000	000

Each tape starts with code '255', followed by 40 cycles of codes indicated by 1 to 8 in the table. Code 200 represents

$$2 \quad = 2 \times 10^{-3} \text{ gr cm}^{-2}\text{s}^{-2}$$

which is taken as the maximum value of $\mathcal{P}$ in Fig. 13.

Test tapes BD2TT-170ϕ and BD2TT-254h

Table 7 Format of the tapes

Ref. No.	START CODE	1 a	2 b	3 c	4 d	5 ϕ	6 h	7 –	8 –
BD2TT-170ϕ	255	000	000	000	000	170	000	000	000
-254h	255	000	000	000	000	000	254	000	000

Each tape starts with code '255', followed by 40 cycles of codes indicated by 1 to 8 in the above table. Code 170 represents

$$1/\sin^2\phi = 1.70$$

and code 254 represents

$$h_a = 2.54 \times 10^4 \text{ cm}$$

both of which are taken as the maximum values of $1/\sin^2\phi$ and h_a respectively in Fig. 13.

Test tape BD2TT-254/154-100/0

Table 8 Format of the tape.

START CODE ↓	1 a	2 b	3 c	4 d	5 ø	6 h	7 –	8 –
255	254	254	154	154	170	254	000	000
	154	154	254	254	170	254	000	000
	254	154	254	154	170	254	000	000
	154	254	154	254	170	254	000	000
	000	000	000	000	000	000	000	000
255	100	100	000	170	254	000	000	000
	000	000	100	100	170	254	000	000
	100	000	100	000	170	254	000	000
	000	100	000	100	170	254	000	000

Table 9 Theoretical values of the output from the tape shown in Table 8.

	1 x	2 y	3 x	4 y	5 x	6 y	7 x	8 y
PXY	254	127	0	127	127	254	127	0
D	79	245	175	9	9	79	245	175
V	254	254	254	254	254	254	254	254
M1	175	9	79	245	245	175	9	79
M2	91	216	163	38	38	91	216	163
M3	96	127	158	127	127	96	127	158
AD	194	38	60	216	216	194	38	60

Each number is rounded to the nearest whole number.

Test tape BD2TT-100ϕVR

This tape represents the value of $1/\sin^2\phi$ varying from 0 to 1.70 with 0.05 steps, while all other values are fixed as follows:

In 'even section'

$h_a = 2.54 \times 10^4$ cm

$p_a = 10^{-3}$ gr cm^{-1} s^{-1}

$p_b = 10^{-3}$ gr cm^{-1} s^{-1}

$p_c = 0$

$p_d = 0$

In 'odd section'

$h_a = 2.54 \times 10^4$ cm

$p_a = 0$

$p_b = 0$

$p_c = 10^{-3}$ gr cm^{-1} s^{-1}

$p_d = 10^{-3}$ gr cm^{-1} s^{-1}

Code 100 in the tape reference number indicates that the maximum value of p_a etc. is taken as 10^{-3} gr cm^{-1} s^{-1}.

Table 10 Format of the tape

p_a	p_b	p_c	p_d	ϕ	h	–	–	p_a	p_b	p_c	p_d	ϕ	h	–	–
							START								
000	000	000	000	000	000	000	$\boxed{255}$	100	100	000	000	100	254	000	000
000	000	100	100	100	254	000	000	100	100	000	000	105	254	000	000
000	000	100	100	105	254	000	000	100	100	000	000	110	254	000	000
000	000	100	100	110	254	000	000	100	100	000	000	115	254	000	000
000	000	100	100	115	254	000	000	100	100	000	000	120	254	000	000
000	000	100	100	120	254	000	000	100	035	000	000	051	290	000	000
000	000	032	032	033	032	000	000	032	032	000	000	130	032	000	000
000	000	032	032	130	186	000	000	032	032	000	000	135	190	000	000
000	000	100	100	135	186	000	000	032	035	000	000	000	032	000	000
000	000	100	100	140	254	000	000	100	100	000	000	145	254	000	000
000	000	100	100	145	254	000	000	036	032	000	000	130	179	000	000
000	000	032	032	000	170	000	000	036	032	000	000	155	186	000	000
000	000	032	035	155	185	000	000	032	032	000	000	160	186	000	000
000	000	032	032	160	042	000	000	032	032	000	000	033	032	000	000
000	000	032	032	151	170	000	000	035	035	000	000	170	180	000	000
000	000	032	032	170	270	000	000	000	000	000	000	000	000	000	000

Test tape BD2TT-100hVR

This tape represents the value of h_a varying from 0 to 2.54×10^4 cm with 10^3 cm steps, while all other values are fixed as follows:

In 'even section'

$1/\sin^2\phi = 1.70$

$p_a = 10^{-3}$ gr cm^{-1} s^{-1}

$p_b = 10^{-3}$ gr cm^{-1} s^{-1}

$p_c = 0$

$p_d = 0$

In 'odd section'

$1/\sin^2\phi = 1.70$

$p_a = 0$

$p_b = 0$

$p_c = 10^{-3}$ gr cm^{-1} s^{-1}

$p_d = 10^{-3}$ gr cm^{-1} s^{-1}

Code 100 in the tape reference number indicates that the maximum value of p_a etc. is taken as 10^{-3} gr cm^{-1} s^{-1}.

Table 11 Format of the tape

p_a	p_b	p_c	p_d	ϕ	h	–	–	p_a	p_b	p_c	p_d	ϕ	h	–	–
							START								
000	000	000	000	000	000	000	$\boxed{255}$	100	100	000	000	170	000	000	000
000	000	100	100	170	000	000	000	100	100	000	000	170	010	000	000
000	000	100	100	170	210	000	000	100	100	000	000	170	020	000	000
000	000	035	035	170	020	000	000	036	036	000	000	170	030	000	000
000	000	100	100	170	030	000	000	100	100	000	000	170	040	000	000
000	000	100	100	170	040	000	000	036	100	000	000	170	050	000	000
000	000	100	035	170	050	000	000	032	036	000	000	170	060	000	000
000	000	100	036	170	060	000	000	130	035	000	000	170	070	000	000
000	000	100	100	170	070	000	000	036	036	000	000	170	080	000	000
000	000	035	036	170	080	000	000	100	036	000	000	170	090	000	000
000	000	100	100	170	090	000	000	100	100	000	000	170	100	000	000
000	000	100	100	170	100	000	000	100	100	000	000	170	110	000	000
000	000	100	100	170	110	000	000	100	100	000	000	170	120	000	000
000	000	100	100	170	120	000	000	100	100	000	000	170	130	000	000
000	000	100	100	170	130	000	000	100	100	000	000	170	140	000	000
000	000	100	100	170	140	000	000	100	100	000	000	170	150	000	000
000	000	100	100	170	150	000	000	100	100	000	000	170	160	000	000
000	000	100	100	170	160	000	000	100	100	000	000	170	170	000	000
000	000	100	100	170	170	000	000	100	100	000	000	170	180	000	000
000	000	100	100	170	180	000	000	100	100	000	000	170	190	000	000
000	000	100	100	170	190	000	000	100	100	000	000	170	200	000	000
000	000	100	100	170	200	000	000	100	100	000	000	170	210	000	000
000	000	100	100	170	210	000	000	100	100	000	000	170	220	000	000
000	000	100	100	170	220	000	000	100	036	000	000	170	166	000	000
000	000	032	036	170	162	000	000	036	036	000	000	170	175	000	000
000	000	036	122	170	240	000	000	100	100	000	000	170	250	000	000
000	000	100	100	170	250	000	000	100	100	000	000	170	254	000	000
000	000	100	100	170	254	000	000	000	000	000	000	000	000	000	000

3.6.2 Synchronization

It is necessary to test the synchronization between BD2 and other circuits before further tests or calibrations are carried out.

The procedure of testing the synchronization is as follows:

1 Set the main control selector (on the main control panel) to TED.

2 Set test tape BD2TT-0 on the tape-reader.

3 Run the motor of the tape-punch.

4 Turn switch FB (on the tape-reader) to B, and leave two switches in GE and R positions respectively.

5 Press switch TAPE FORWARD (green arrow on the tape-punch) momentarily.

If the whole system is working properly, the input and output tapes will run in synchronization. When correctly synchronized, 2 increments on the output tape correspond to 8 increments on the output tape.

3.6.3 Test procedure

For the later paragraphs (1) to (8), test procedures are expressed in a simplified form of tables. For example,

Input (V)	Adjust	Output (V)
SY = +5.00	Fx	TX = +3.50

should be read as:- "Feed +5.00V to input terminal SY, and adjust preset resistor Fx to obtain +3.50V at output terminal TX." Also, for example, "SW2 to CL" should be read as "Set switch 2 to CL side." See page 67 for symbols.

(1) Calibration of the standard voltage on BD2

SW2 (MIP panel)	to	CL
SW (")	to	F
TO (")	to	DVM (4 digit)

Then adjust REF (on BD2) to obtain +5.00V at TO.

(2) Calibration of the tape output scale

Main function control (on the main control cabinet)	to	TED
SW-VN (MIP panel)	to	N
SW-FB (Tape-reader)	to	F
Momentum SW (Keyboard)		Press

Then follow Table 12.

Table 12 Output scale setting

Order	Switches on M1U panel		Adjust	Output on tape	
	BIAS	CL		DEC	BIN
1	ON	Z	BIAS 8 (M1U panel)	127	0111 1111
2	ON	F	G8 (BD2)	254	1111 1110
3	OFF	Z	-	0	0000 0000

(3) Input channels a, b, c, d

Table 13 Zero setting

Input	Adjust	Output (V)
Tape BD2TT-0	Za	0.00
"	Zb	"
"	Zc	"
"	Zd	"

Measure each voltage at T1 (MD panel) by setting ST1 (MD panel) to a, b, c or d.

Table 14 Full-scale setting

Input	Adjust	Output (V)	
Tape BD2TT-200a	Fa	PX = +5.00	PY = +5.00
-200b	Fb	PX = +5.00	PY = -5.00
-200c	Fc	PX = -5.00	PY = +5.00
-200d	Fd	PX = -5.00	PY = -5.00

The absolute values at PX and PY should agree to within ±0.3%. Measure each output voltage at T1 by setting ST1 to PX or PY.

(4) Input channels ϕ and h

Table 15 Zero setting

Input	Adjust	Output (V)
Tape BD2TT-0	Zϕ	0.00
"	Zh	"

Table 16 Full-scale setting

Input	Adjust	Output (V)
Tape BD2TT-ϕ	FFϕ	Eϕ
-h	FFh	Eh

Measure the output voltage at T1 by setting SW1 to ϕ or h. The values of E_ϕ and E_h are given by equations (11) and (12) generally. These values in the above table are E_ϕ = 5V and E_h = 5V.

(5) Computing unit VSU

Disconnect JOINTs PX-SX and PY-SY (BD2).

Table 17 Zero setting

Input (V)	Adjust	Output (V)
SX = 0.00, SY = 0.00	Zv	0.00

Table 18 Full-scale setting

Input (V)	Adjust	Output (V)
SX = +5.00, SY = +5.00	Fv	+7.071
SX = -5.00, SY = -5.00	Confirm	+7.071

$$\sqrt{5^2 + 5^2} = 7.071$$

Measure each output voltage at TO (MD panel) by setting STO (MD panel) to V.

(6) Computing unit VRU

Table 19 Zero setting

Input (V)	Adjust	Output (V)
SX = 0.00, SY = 0.00	ZD1	PD1 = 0.00
SX = 0.00, SY = 0.00	ZD2	PD2 = 0.00

Table 20 Full-scale setting

*	Input (V)	Adjust	Output (V)
1	SX = 0.00, SY = +5.00	D2SIN	PD2 = +Es
2	" "	D1COS	PD1 = -Ec
3	SX = +5.00, SY = 0.00	D2COS	PD2 = -Ec
4	" "	D1SIN	PD1 = -Es
5	SX = 0.00, SY = -5.00	Confirm	PD2 = -Es
6	" "	"	PD1 = +Ec
7	SX = -5.00, SY = 0.00	"	PD2 = +Ec
8	" "	"	PD1 = +Es

Measure each output voltage at TO by setting STO to DX or DY.

The full-scale setting of this unit involves the setting of sin δ and cos δ for both the x and the y components (i.e. four constants in all). The values of Es and Ec depend on the value of δ. For example, if $\delta = 22^{\circ}$, then

$$Es = 5\ (V)\ \sin 22^{\circ} = 1.873\ (V)$$

$$Ec = 5\ (V)\ \cos 22^{\circ} = 4.636\ (V)$$

Use an external power source for +5V or -5V.

*The adjustments should be carried out in this order.

(7) Multiplying units, M1U, M2U, M3U

The three units have the same construction, except for their multiplying factors. The setting procedure for M1U only is explained. When Tables and are applied to M2U and M3U, symbols M1A, M1Z etc. in these tables should be read as M2A, M2Z etc. or M3A, M3Z etc.

Disconnect JOINTs VO-M1A and VD-M1B.

Table 21 Zero setting

*	Input (V)	Adjust	Output (V)
1	M1A = 5 pk-pk ac, M1B = 0	M1ZB	M1AB = 0 ac
2	M1A = 0, M1B = 5 pk-pk ac	M1ZA	"
3	M1A = 0, M1B = 0	M1ZO	"

ac = sin wave, 1 kHz approx.

Table 22 Full-scale setting

*	Input (V)	Adjust	Output (V)
4	M1A = +5.00, M1B = +5.00	M1F	M1AB = Em**
5	M1A = -5.00, M1B = -5.00	Confirm	"

Measure each output voltage at TO by setting M1, M2 or M3.

* The adjustments should be carried out in this order.
**If the value of Em in 4 and 5 disagrees by more than 20 mV (0.4%), the adjustments have to be repeated in the order described. In practice, once the outputs in 4 and 5 are agreed, M2F can be adjusted to any different value of Em, without readjusting 1 to 3.

The value of E_m for each unit is as follows:

M1U From Fig. 14, $E_{m1} = 5.00V$

M2U From equation (20), $E_{m2} = E_{M2AB} = 3.767V$

M3U From equation (21), $E_{m3} = E_{M3AB} = 1.222V$

(8) Test of the whole system

1 Apply test tape BD2TT-254/154-100/0 to the tape-reader.

2 Make the tape-reader ready to run.

3	(MP) MC	to	TED
4	(MD) V	to	N
5	(MD) STO	to	AD
6	(TR) F	to	F
7	(KB) MS		Press

(or pull the tape momentarily).

Then the tape will print the output. The output should be accurately compared with the theoretical values shown in Table 9. (See page 67 for symbols).

3.7 Performance

In order to demonstrate the performance of the computing unit, characteristics of some computing sub-units, and results of overall characteristics of the whole unit are shown in this paragraph.

Fig. 20 shows the linearity and zero-crossing of the absolute-value computing circuits (ABVs in Fig. 14), in the x and y components.

Fig. 21 shows the characteristics of the vector-sum computing circuit (VSU in Fig. 15b). Both Fig. 20 and Fig. 21 are reduced copies of xy-plotter records, and the results are satisfactory.

Fig. 22 shows the transfer characteristic of the ADC. This is also satisfactory.

Figs. 23, 24 and Table 23 show the accuracy of combined operation of the whole computing unit.

Fig. 23 shows the directions of wind and wind stress computed from the atmospheric pressure values, compared with their theoretical values.

Fig. 24 shows the linearities of various wind speeds (a), and those of wind stress (b), in a fixed direction. The x and y components of wind speed and wind stress are compared with the theoretical values. These are also satisfactory.

Table 23 shows an example of overall test results obtained by using test tape BDTT254/154-100/0 (page 38). The values are sampled at various stages of computation (indicated by PXY, D, V, M1, M2, M3 and AD). The test was repeated twice, and the results are shown in two lines in each test factor. The differences of the values from the theoretical values are shown by numbers in italics; ±1 corresponds to ±0.4% of the full scale.

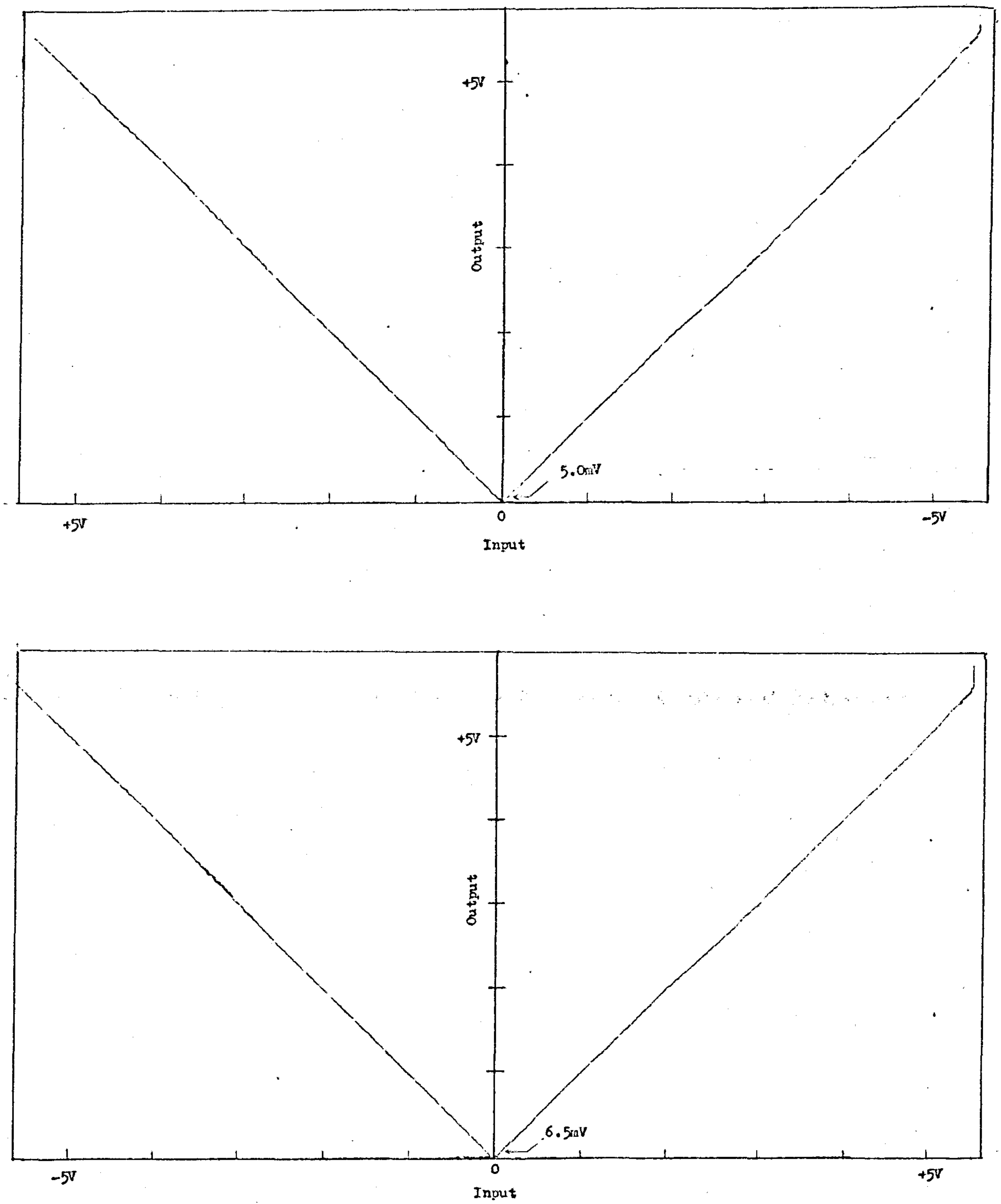


Fig. 20 Characteristics of the absolute-value circuit, ABU.
Top: X component. Bottom: Y component.

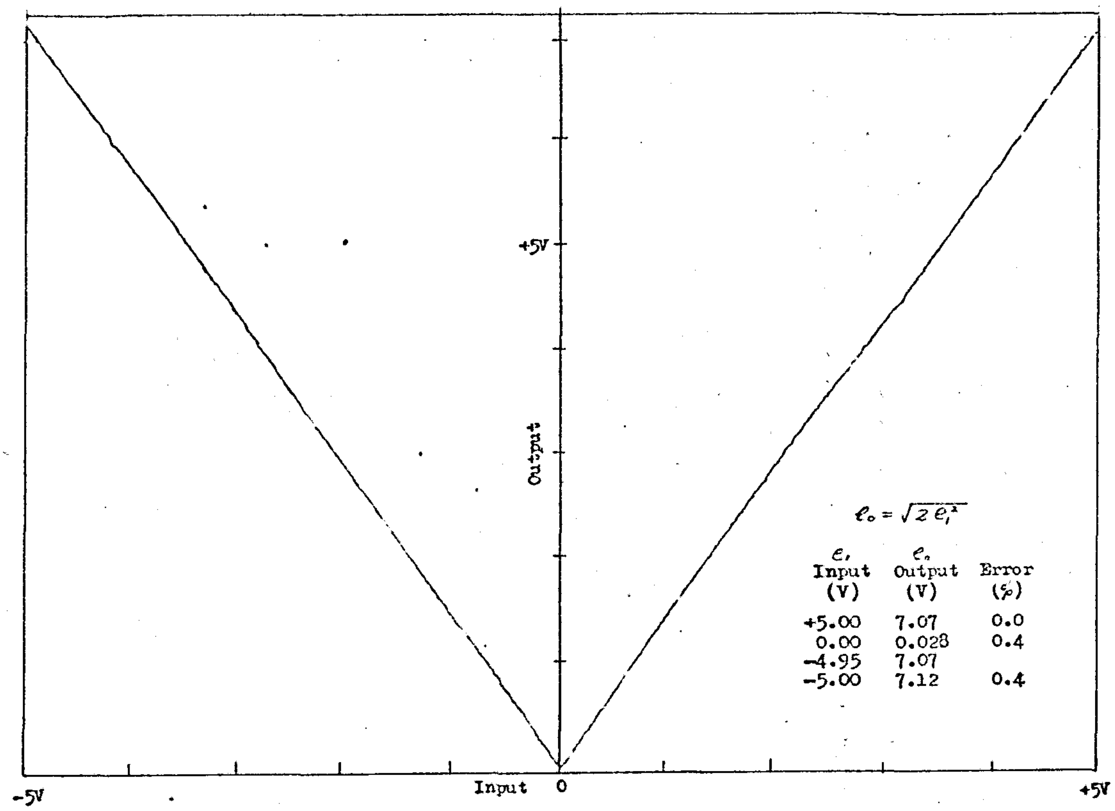


Fig. 21 Characteristic of the vector-sum circuit, VSU.

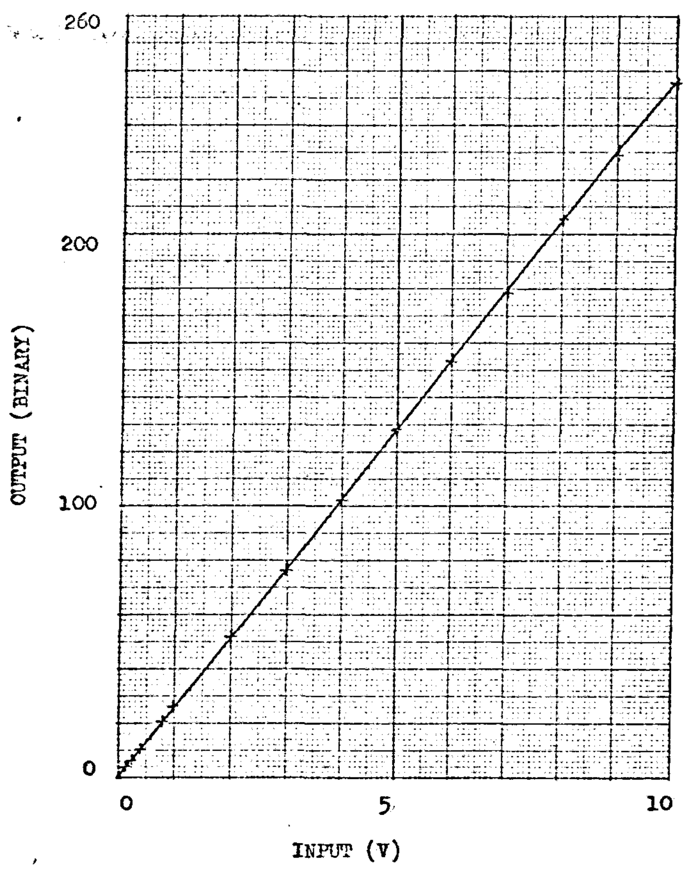


Fig. 22 Characteristic of the DAC contained in BD2.

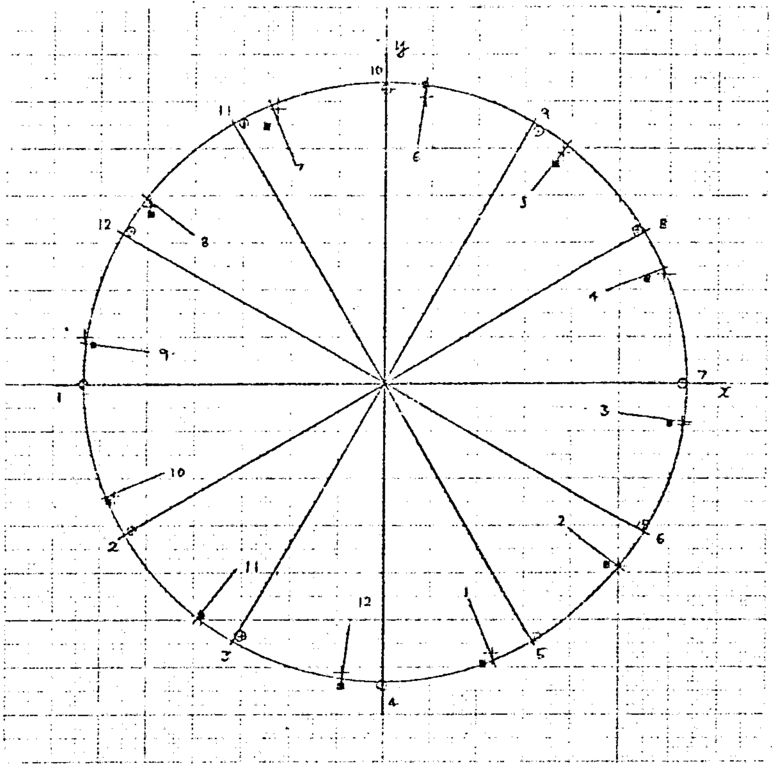


Fig. 23 Examples of the accuracy of complex computations with BD2.

o : Computed direction of the atmospheric pressure gradient.
+ : Computed direction of wind, from the pressure gradient.
▪ : Computed direction of stress on the sea surface, from the wind.

Line near each value shows its theoretical value.

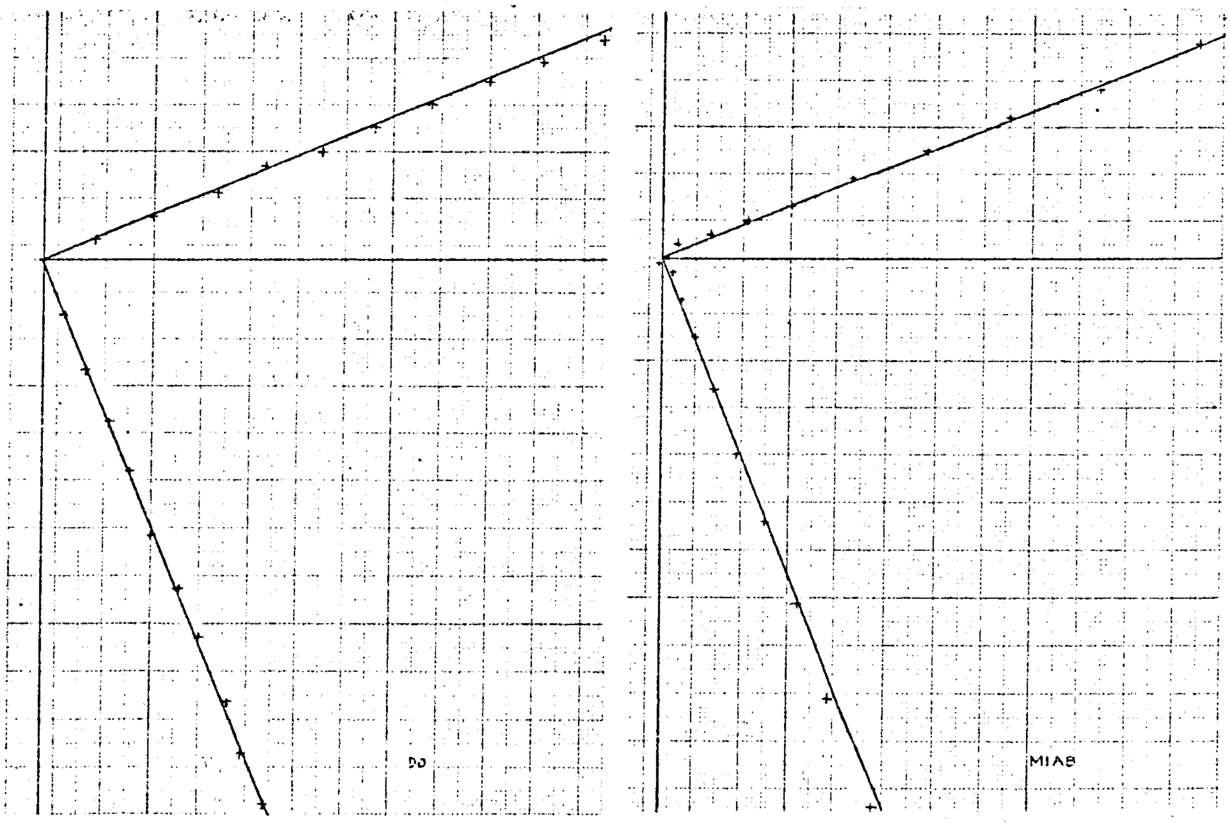


Fig. 24 Examples of the accuracy of complex computations with BD2.

Left : Various wind speeds in two constant directions.
Right : Values of stress on the sea surface due to various wind speeds in two constant directions.

Lines show their theoretical values.

Table 23 Examples of the accuracy of complex computations with BD2.
Input: Test tape BDTT-254/154-100/0 (see page 38).
Output: From 7 different stages of the computation, shown by PXY, D, etc.
Numbers shown by a computer printer: computed values.
Numbers in italics: difference of the computed values with reference to the theoretical values (see Table 9).

	1	2	3	4	5	6	7	8	REFERENCE (127)
PXY	253 254	126 126	001 000	126 125	125 128	253 253	127 127	002 001	125 125 127 127 127 125 128 127 127 125 127 127
	-1 *0*	*-1* *-1*	*1* *0*	*-1* *-1*	*-1* *1*	*-1* *-1*	*0* *0*	*0* *1*	*±1*
D	078 078	245 243	173 173	085 085	085 085	077 077	244 244	174 173	127 128 127 127 127 128 127 128 127 127 127 128
	-1 *-1*	*0* *-2*	*-2* *-2*	*-4* *-4*	*-3* *-3*	*-2* *-2*	*-1* *-1*	*-1* *-1*	*±1*
V	253 253	253 253	254 255	255 253	254 254	254 253	255 255	254 254	127 127 127 127 127 127 127 127 127 127 127 127
	-1 *-1*	*-1* *-1*	*0* *1*	*1* *-1*	*0* *0*	*0* *1*	*1* *1*	*0* *0*	*±1*
M1	175 175	227 227	079 079	245 246	244 244	175 175	001 000	078 079	129 129 129 129 129 129 129 129 129 129 129 129
	1 *1*	*-2* *-2*	*0* *0*	*0* *0*	*-1* *-1*	*0* *0*	*-8* *-9*	*1* *0*	*±2*
M2	089 089	213 213	151 152	034 035	035 035	090 089	214 214	161 161	127 126 125 127 125 125 127 125 125 125 127 127
	-3 *-3*	*-3* *-3*	*-2* *-1*	*-4* *-3*	*-2* *-3*	*-1* *-2*	*-2* *-2*	*-2* *-2*	*-1* *0*
M3	095 095	127 128	156 155	127 127	127 127	095 095	127 126	155 155	127 128 127 128 127 128 127 126 128 127 129 127
	-1 *-1*	*0* *1*	*2* *2*	*0* *0*	*0* *0*	*-1* *-1*	*0* *1*	*2* *2*	*+2* *-1*
AD	193 193	037 036	059 060	214 215	215 215	193 193	035 035	058 059	128 127 126 126 126 126 127 126 127 127 126 125
	-1 *-1*	*-1* *-2*	*-1* *0*	*-2* *-1*	*-2* *-1*	*-1* *-1*	*-3* *-3*	*2* *1*	*+2* *-1*

4. VECTOR PLOTTING UNIT

Most meteorological input data for surge analysis is in a vector quantity, such as the atmospheric pressure gradient or wind. Most surge data which is the output of the whole model is also in a vector quantity, such as the x and y components of water currents. It is convenient, therefore, to display the data involved at most stages of computation, including the final output, without using external facilities in software and hardware. The vector plotting unit described in this chapter satisfies this demand.

4.1 Principle

A set of data from which the vectors are plotted is recorded on a tape in the following form:-

$$(x, y, X, Y)_1, \quad (x, y, X, Y)_2, \quad \ldots\ldots \quad (x, y, X, Y)_n$$

where X and Y are the coordinates of a grid, G (in Fig. 25), whose origin is at a certain position on the map, 0; x and y are the coordinates of the 'top' of a vector whose origin is on G; and a set of brackets with suffix indicates a set of data for one vector. The method of producing such a tape simply and quickly will be described later.

The electronic circuit has been designed so that the pen of the XY-plotter moves from 0 to G without drawing any line, and then moves from G to P drawing a line. After the completion of a vector, the pen moves to another vector without drawing any line, and repeats the same action until all the vectors on a map have been completed.

In order to move the pen from G to P for each vector, a set of representing voltages

$$X + x(t) \qquad \text{and} \qquad Y + y(t)$$

are required. $x(t)$ and $y(t)$ simultaneously change with time from zero to the maximum of each value.

x and y in this treatment must be bipolar, while they are recorded on the tape in the monopolar form. Therefore a conversion from a monopolar form to a bipolar form is required.

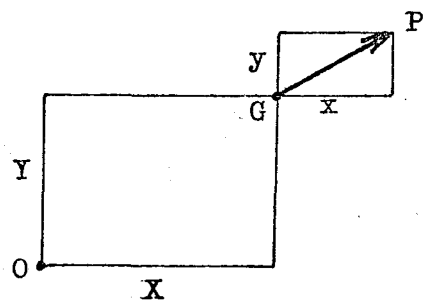


Fig. 25 Scheme of plotting a vector on a map. O : Origin for X and Y. G : Origin for x and y. P : Top of a vector.

The above mentioned two requirements (the generation of a time-varying voltage and the polar-form conversion) are carried out at the same time by the circuit described in this paper. Fig. 28 shows the principle of this operation. In the top line of the figure, examples of three different values, x = 250, 127 and 0, in a monopolar form are shown. A voltage representing each value changes with time from zero to each value linearly. In the second line, a voltage which changes with time from zero to -127 linearly is shown. Now when this voltage is added to each voltage in the top line, a bipolar voltage which changes with time from zero to a certain value is obtained, as shown in the bottom line. The same operation is carried out for the y component. Finally X and Y are added to x(t)-127(t) and y(t)-127 respectively.

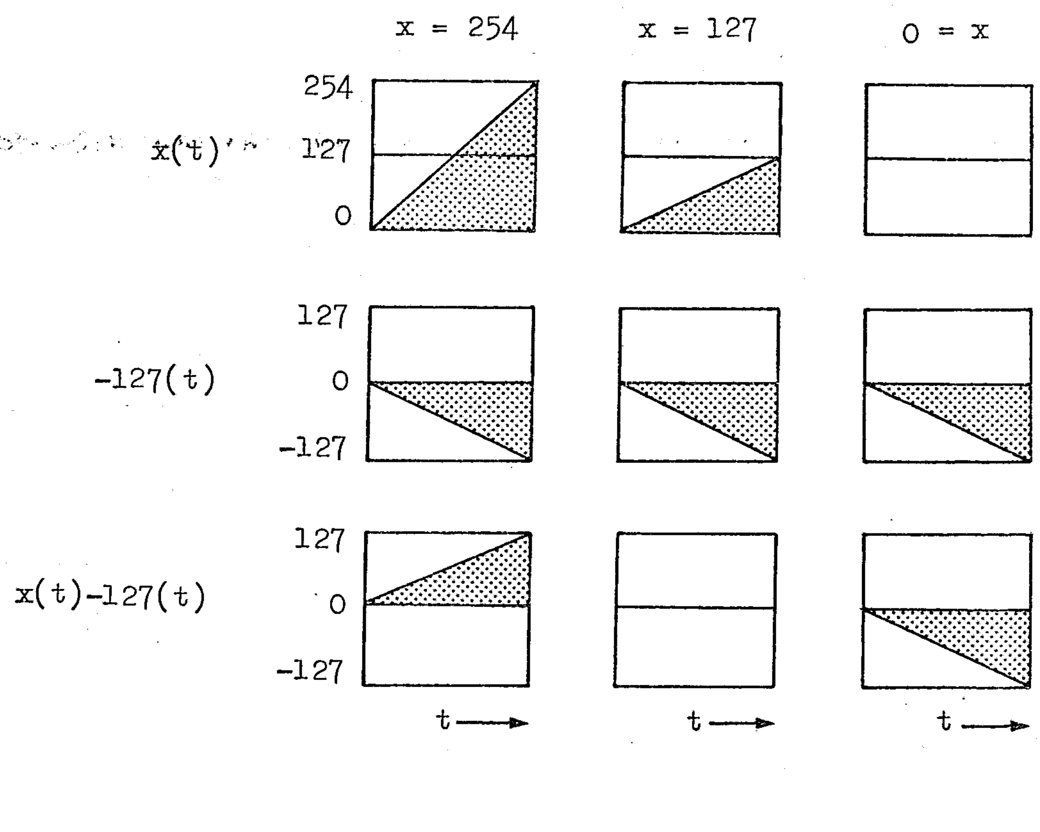


Fig. 26 Principle of generating a time-varying voltage, by which the plotter pen is driven from the origin of a vector to its top, and at the same time, the data changes from a monopolar form to bipolar form.

4.2 Scheme of the vector plotting circuit

Fig. 27 shows the block diagram by which the above-mentioned principle is realized. Fig. 28 shows the timing diagram for this circuit, with the indication of its terminal numbers (see Fig. 31).

Serial-to-parallel conversion The input data are recorded on the tape in a serial form. Every set of four values, x, y, X, Y, are read continuously for 8 milli seconds by the tape-reader. Through the serial-to-parallel converter, each value is stored in a memory until the drawing of a vector has been completed.

DACs The stored value (binary coded digital signal) is converted into an analogue voltage by each multiplying-type DAC. The DACs for x and y are operated with a time-varying reference voltage so that their output changes with time from zero to x or y linearly. The DACs for X and Y are operated with a fixed reference voltage.

Ramp-voltage generator This generator has two outputs: one produces positive-going ramps, and the other negative-going ramps. The former is used for the reference voltages for the DACs for x and y. The latter is used for the polar-form conversion (explained in the previous chapter).

Adding and scaling circuits The output of the DAC for x and the negative-going ramp voltage are added and scaled by one of these circuits. The same operation is carried out for the y component by the other circuit.

Sign reversing and x-y interchange circuits For some applications in a vector display, it is convenient to change the sign of x and/or y, and also to interchange x and y; for example, wind vectors which are customarily indicated by an arrow pointing to a grid. Table 24 and Fig. 29 show the relationship between the signs of x and y, the vector reference angle, and the positions of the switches to control them.

Final adding circuits x and X, and also y and Y are added respectively by a pair of adding circuits, so that the (x) and (Y) components of the XY-plotter are controlled.

Timing circuit Timing control is required for:-
(1) start and stop of the tape for each vector plotting,
(2) clock for the serial-to-parallel conversion,
(3) waiting time during which the pen moves between adjacent grids,
(4) generation of the ramp voltages, and
(5) vertical movement of the pen (touching or not touching the paper).

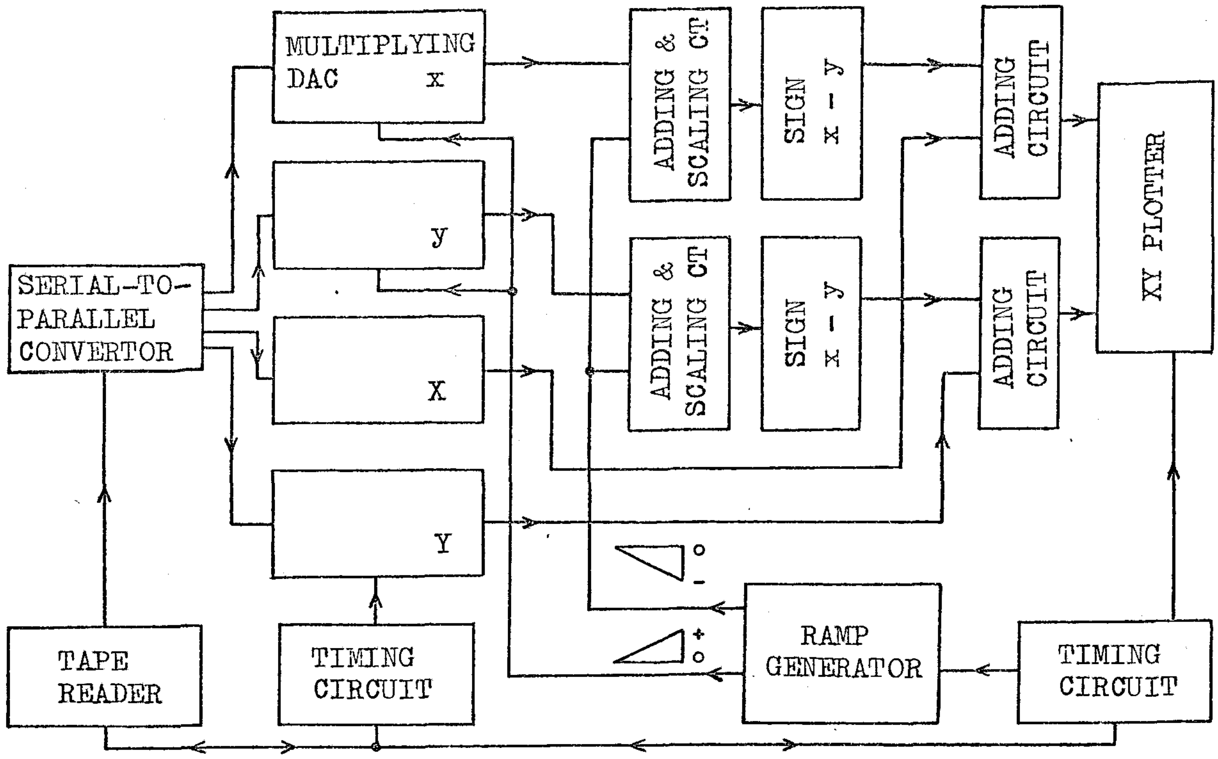
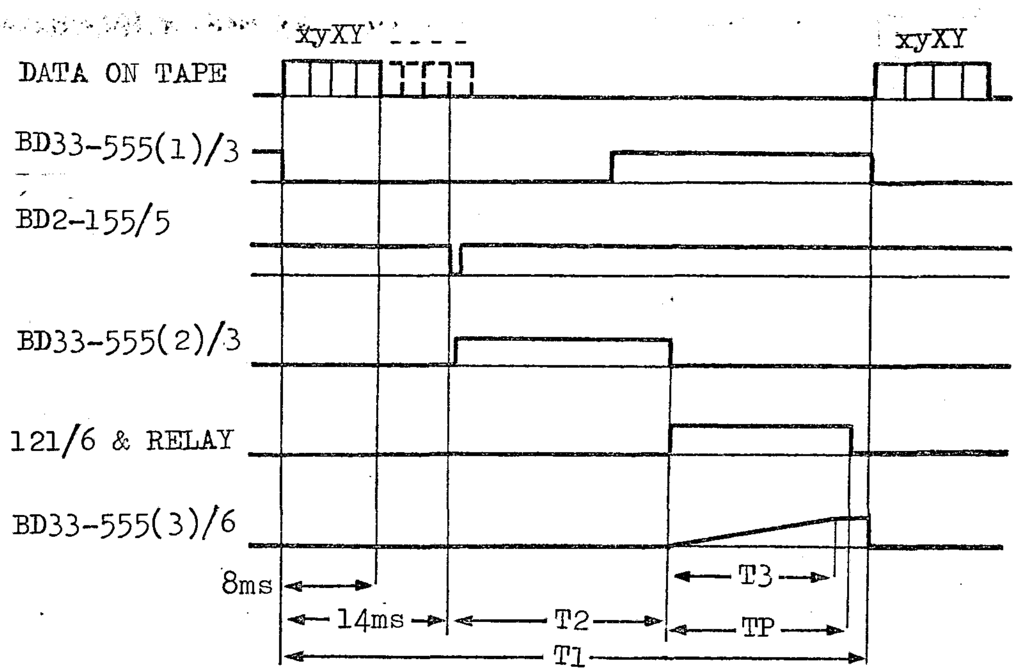


Fig. 27 Block diagram of the vector plotting circuit.



T1 = R_2C_2 : ONE CYCLE
T2 = R_3C_3 : TRANSIENT OF X Y
T3 = : RAMP
TP = 0.7 R_4C_4 : PEN DROP

Fig. 28 Timing diagram of the circuit shown in Fig. 27.

Table 24 Combinations of sign switches (on MD panel) for changing the reference angle of vectors, without changing Tape B.

Change required	Sign switch x	Sign switch y	x-y interchange switch
α	+	+	N
$90^{\circ} + \alpha$	−	+	C
$180^{\circ} + \alpha$	−	−	N
$270^{\circ} + \alpha$	+	−	C
$90^{\circ} - \alpha$	+	+	C
$180^{\circ} - \alpha$	−	+	N
$270^{\circ} - \alpha$	−	−	C
$360^{\circ} - \alpha$	+	−	N

α : Angle of a vector with reference to the normal coordinate.
N : Normal position. C : Interchange position.

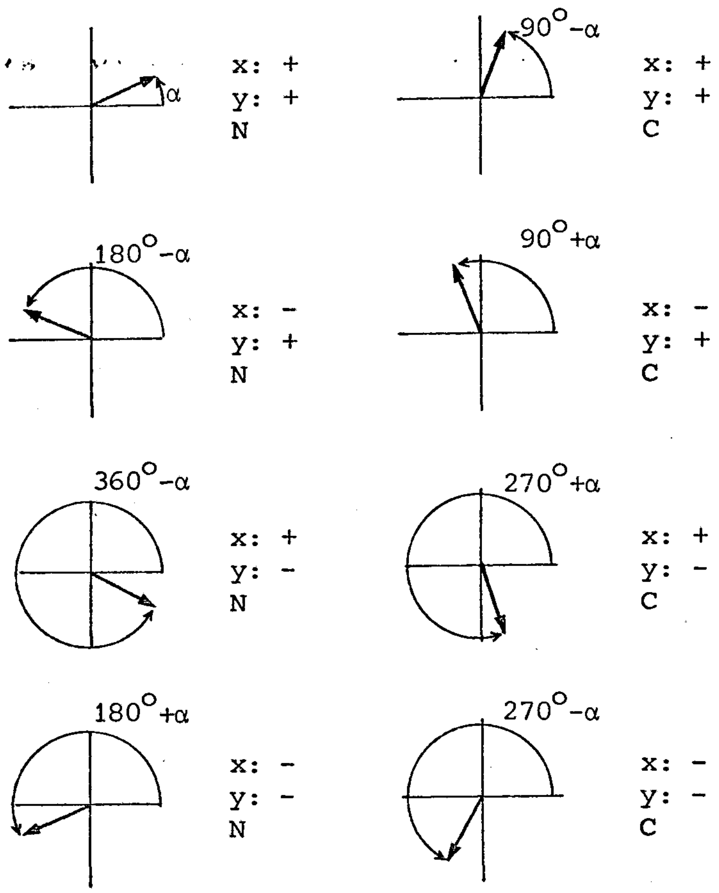


Fig. 29 Variations of the reference coordinate of a vector, produced by controlling the sign switches on MD panel, without changing Tape B. See Table 24 for symbols. See page 68 for MD panel.

4.3 Circuit description

Figs. 30a and 30b show the circuit by which the scheme shown in Fig. 27 is realized. Fig. 30a shows a part of BD2 and a switch, SG4, by which the two modes of operation are selected: (N) BD2 is used as the computing unit, and (V) a part of BD2 is utilized as a data-holding circuit, and combined with BD33. Table 25 shows the function of switch GS4.

Table 25 Function of switch GS4

Signal	N mode	V mode
Analogue voltage from the four DACs	To the internal circuits within BD2	To BD33 and the internal circuits in BD2
Reference voltage for DAC-x and DAC-y	Constant voltage from the internal source of DAC	Time-varying voltage from BD33
Signal to start the tape	Twice per set of words, from the tape-punch	One per set of words, from BD33
Signal to stop the tape	At the 7th and 8th words, from BD2-00/6	At the 7th word only, from BD2-155/4

All the four words (x, y, X, Y) are fed into four units of memory (IC75s) in series, but each memory is activated only when an appropriate word arrives. This timing is controlled by IC155. The memorized word in each channel is converted to an analogue voltage by the ADC (multiplying type). The reference voltages of DAC-x and DAC-y are in a time-varying form (ramp waveform), while those for DAC-X and DAC-Y are constant voltages.

Figs. 32 and 33 show the circuit diagram of BD33.

Timing circuit consists of four timers. 555(1) generates pulses having the period of T1 (see Fig. 5) which is the time required for one vector. This period can be adjusted by preset resistor T1. Each pulse from this circuit starts the movement of the tape. 555(2) is a delay circuit. This is triggered by a pulse which is generated by IC155/5, when the 7th word of each section of data is entered into the system. 555(2) generates another pulse which is delayed from the trigger pulse by the period of T2. This period can be adjusted by preset resistor T2. 555(3) generates a ramp voltage (at its terminal 7) when the delayed pulse from 555(2) arrives. 555(3) also generates a square pulse simultaneously. Both the pulses have a period of T3. This is adjusted by preset resistor T3. The square pulse is used for driving IC121 by which the XY-plotter pen (touching or not touching the paper) is controlled through a transistor and a relay. The period of the pen touching the paper, TP, can be adjusted by preset resistor 'TP'.

The ramp voltage generated by 555(3) is taken out through a buffer circuit and inverter, 747(1), so that a positive-going ramp and negative-going ramp are obtained. The amplitude of the former is adjustable by preset resistor 'B', and that of the latter by preset resistor 'B'. Since the former must not exceed +5.5V (the absolute maximum for the DACs), this is limited by a diode and zener diode.

All the four analogue voltages entering into BD33 are already scaled for the original application of BD2, and must not be disturbed by this extended application of BD33. Therefore, another buffer with a scaling circuit (or a preset resistor) is provided for each channel in BD33, i.e. 747(2) for the X and Y channels, and 747(3) for the x and y channels. These voltages are adjustable by preset resistors 'X', 'Y', 'x' and 'y'.

For the scaling of x and y, relative to the scale of X and Y, a set of x and y scaling circuits, which have the ratios of 1, 2 and 5, have been prepared.

The four analogue voltages, X and x, and Y and y, are added respectively by two adding circuits, 747(4) (a dual amplifier), each of which has two inverted inputs and one non-inverted input. Each output is fed into the XY-plotter.

The sign reversing and x-y interchanging are carried out by the combination of 6 switches which are set between the output of 747(3) and the input of 747(4).

The power requirement for BD33 alone is +5V (10 mA), +15V (14 mA) and -15V (14 mA).

4.4 Physical arrangement

Fig. 31 shows the arrangement of components on BD33. All the components have been mounted on a standard circuit board. The bottom part of the board has been used for the vector plotting circuit, and the top part of the board has been used for the arrow drawing circuit (see Appendix 3).

The whole board has been contained in the case shown in Fig. 17, together with board BD2. All the controls for BD33 and BD2, including switch GS4 are mounted on the common panel of the case.

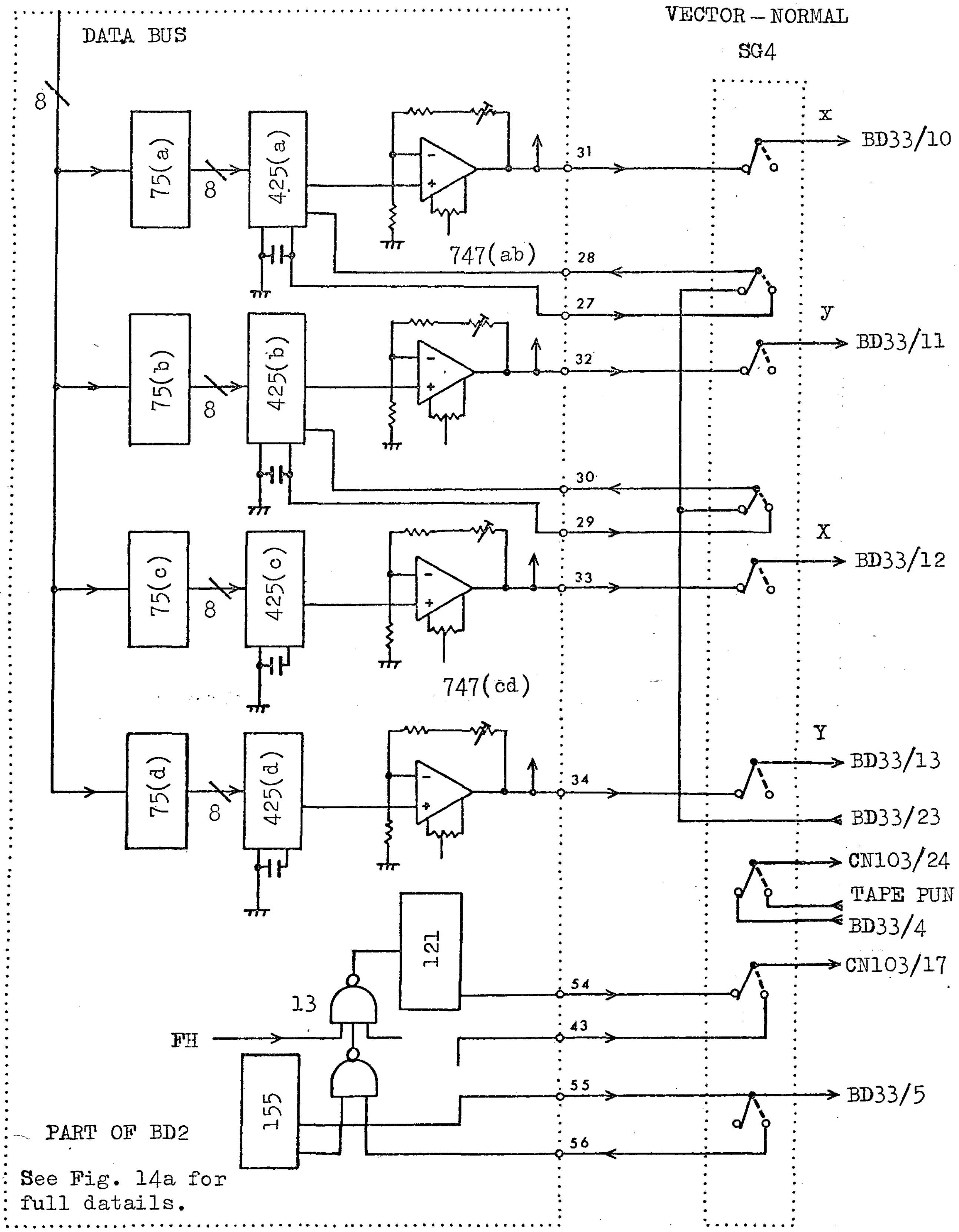


Fig. 30a A part of circuit BD2, and switch SG4 by which BD2 and BD33 are combined.

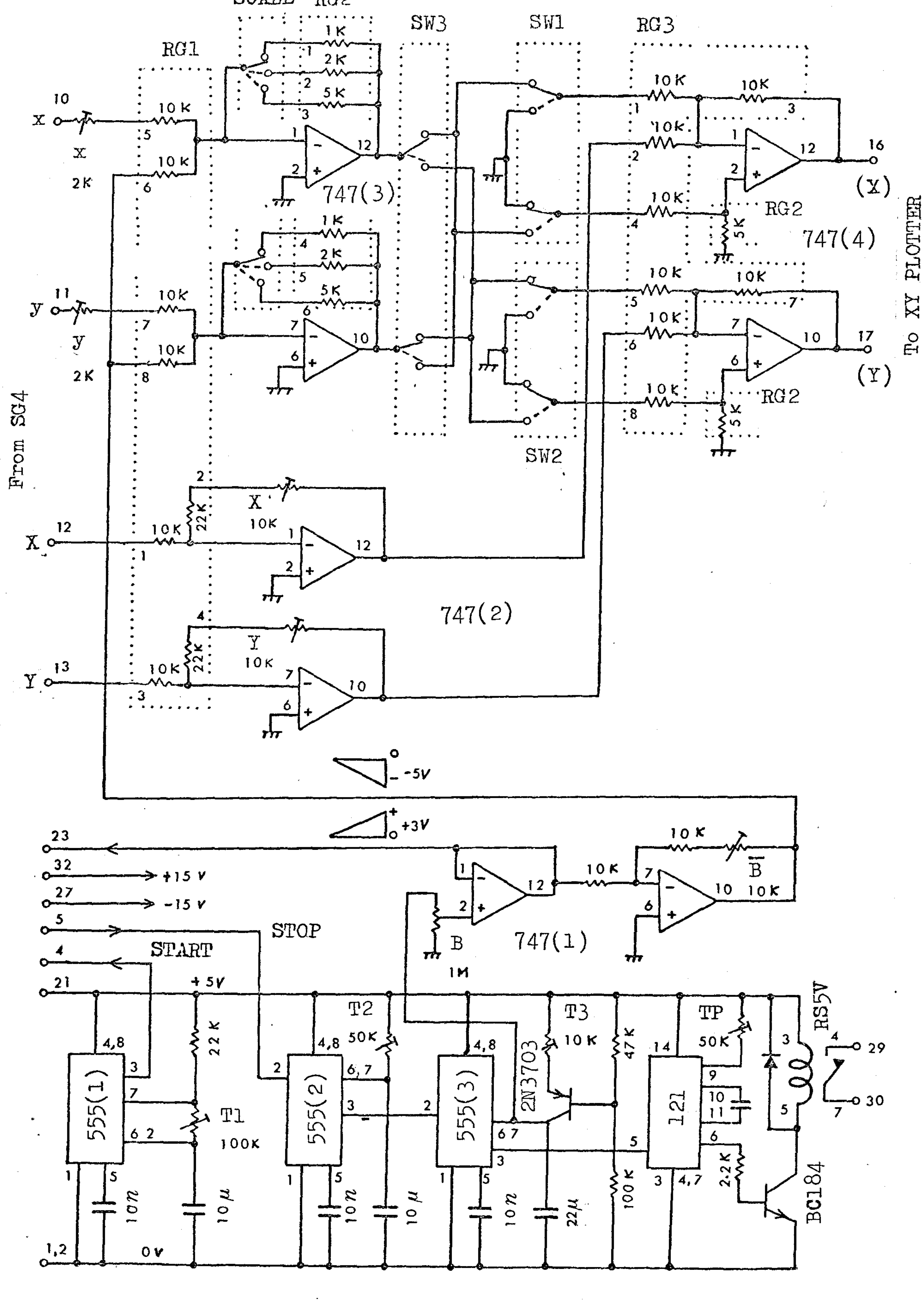


Fig. 30b Vector plotting circuit, BD33.

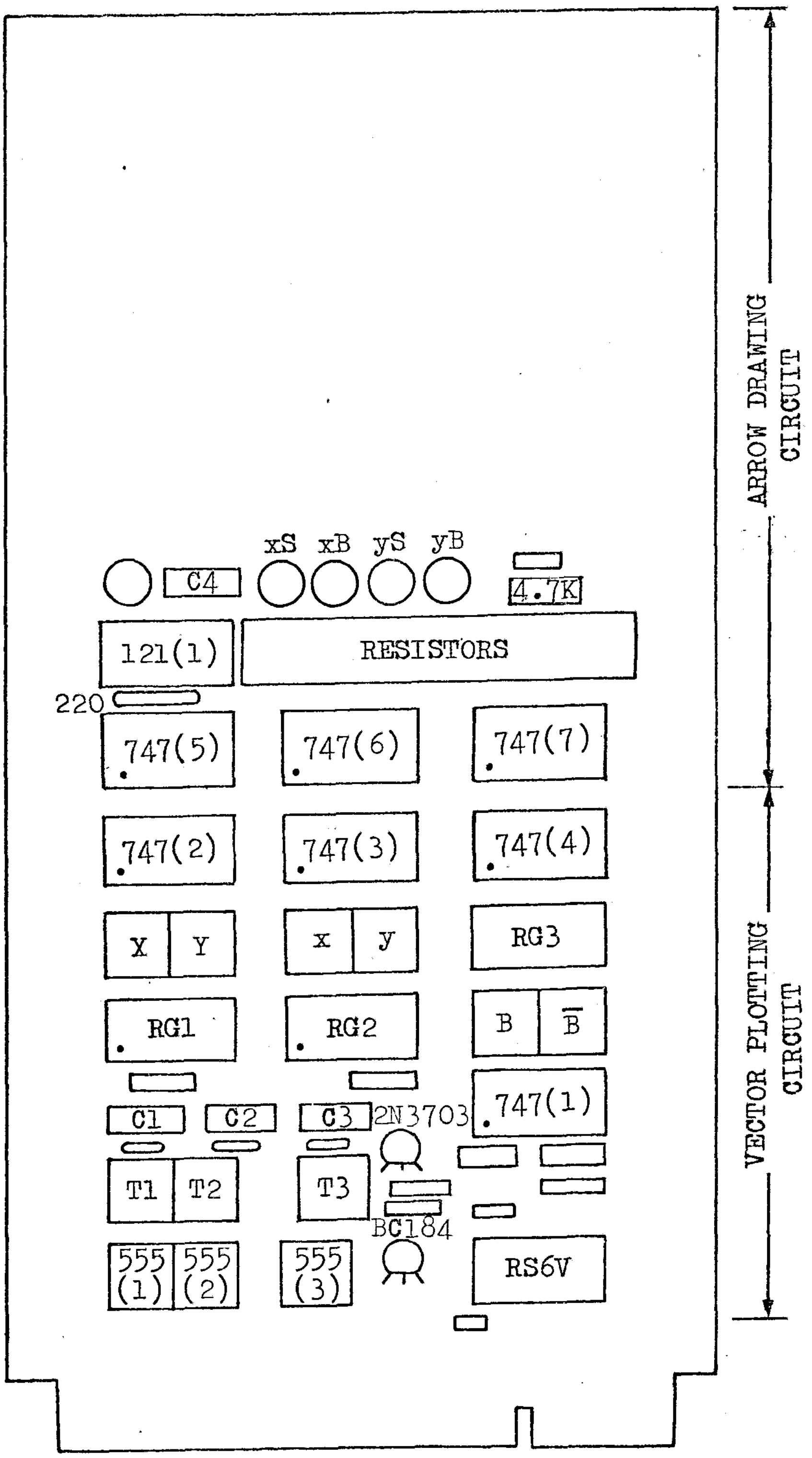


Fig. 31 Arrangement of the components on BD33.
See Appendix 3 for the arrow drawing circuit.

4.5 Linearity of drawing a vector

When the line indicating a vector is drawn on paper by the XY-plotter, this should of course be straight, from its origin to the top of the vector. This can be achieved only when the plotter pen moves proportionally in its x and y components. If not, the difference is shown as a deviation from a straight line. Note the movement of the pen does not have to be linear against time; i.e. the non-linearity of the pen movement against time only changes the drawing speed within a vector line, and cannot be detected after the drawing has been completed.

Generating a set of voltages by which the pen is driven proportionally in its x and y components, can easily be achieved. However, the pen does not exactly follow the voltages at a high speed, since dynamic characteristics of the pen movements in the x and y directions are not equal. Usually the mass of the moving parts in one direction is greater than that in the other direction, and also their damping constants are different, as shown in Fig. 32. These differences become conspicuous when the acceleration or deceleration of the pen is great, as shown in Fig. 33.

Fig. 34 shows examples of waveforms of the electrical inputs in the x and y components, their mechanical responses, and the vectors drawn by these waveforms. (a) requires the shortest drawing time, but the quality of the vector drawn is poor. (b) requires a longer drawing time, but the longer the time the higher the quality obtained. (c) offers a good quality with a relatively short time, but a special circuit is required.

The present system employs method (b), allowing about 0.8 second for completing one cycle of vector drawing. When a line is long (say 5 cm), a slight irregularity can be seen. Method (c) has been tested successfully, but has not been added to the existing system, in order to avoid a further modification.

Note: The maximum writing speed and acceleration of the XY-plotter used are given by its manufacturer:-

Component	Max. writing speed (cm/s)	Max. acceleration (cm/s^2)
X	88	2250
Y	125	3400

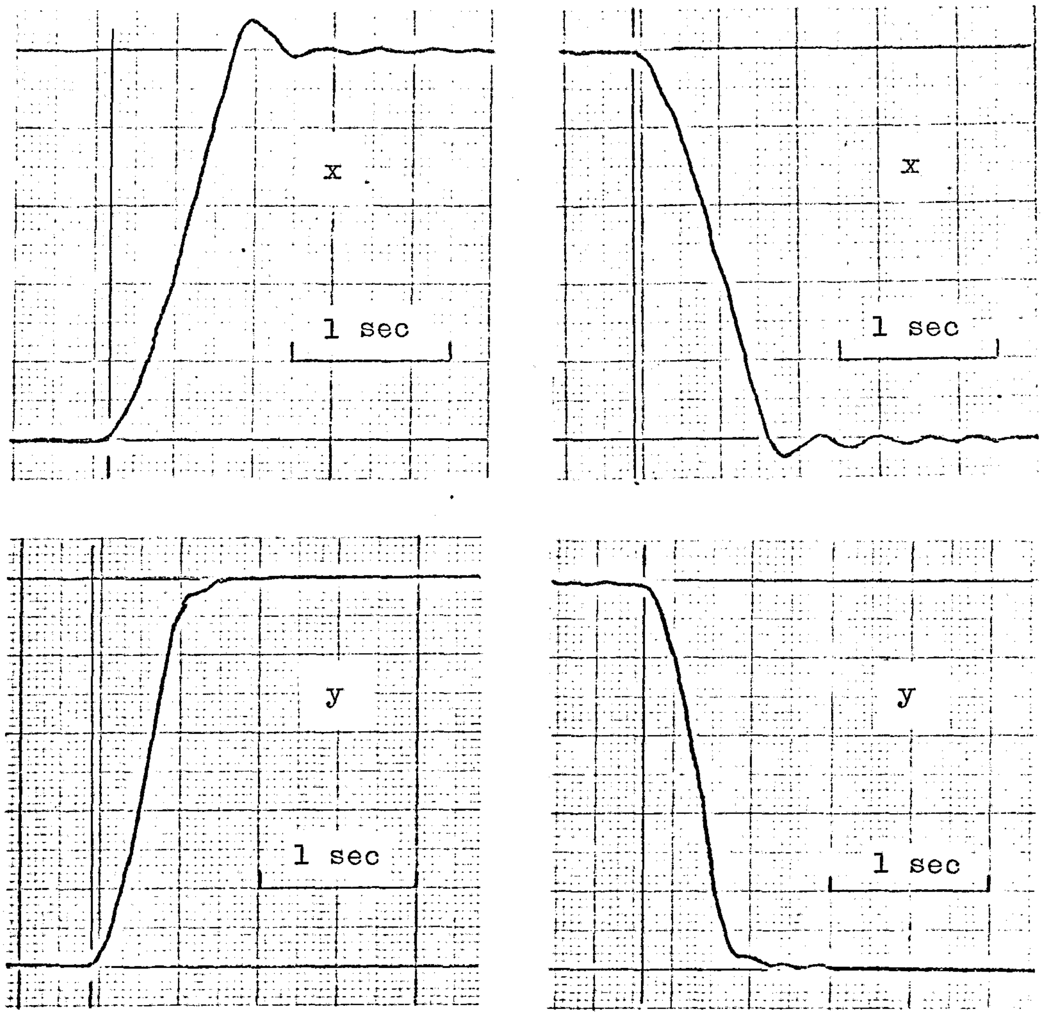


Fig. 32 Responses of the xy-plotter pen movement to a step voltage input, showing the difference between the x and y components.

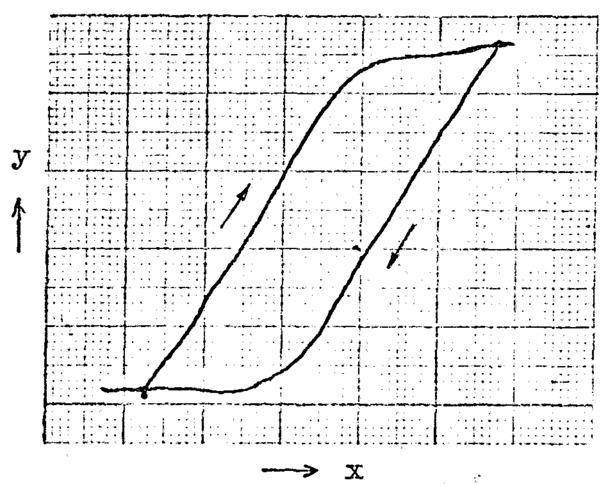


Fig. 33 Movement of the pen on the xy coordinates driven by a step voltage input, showing a hysteresis loop which should be a single straight line ideally.

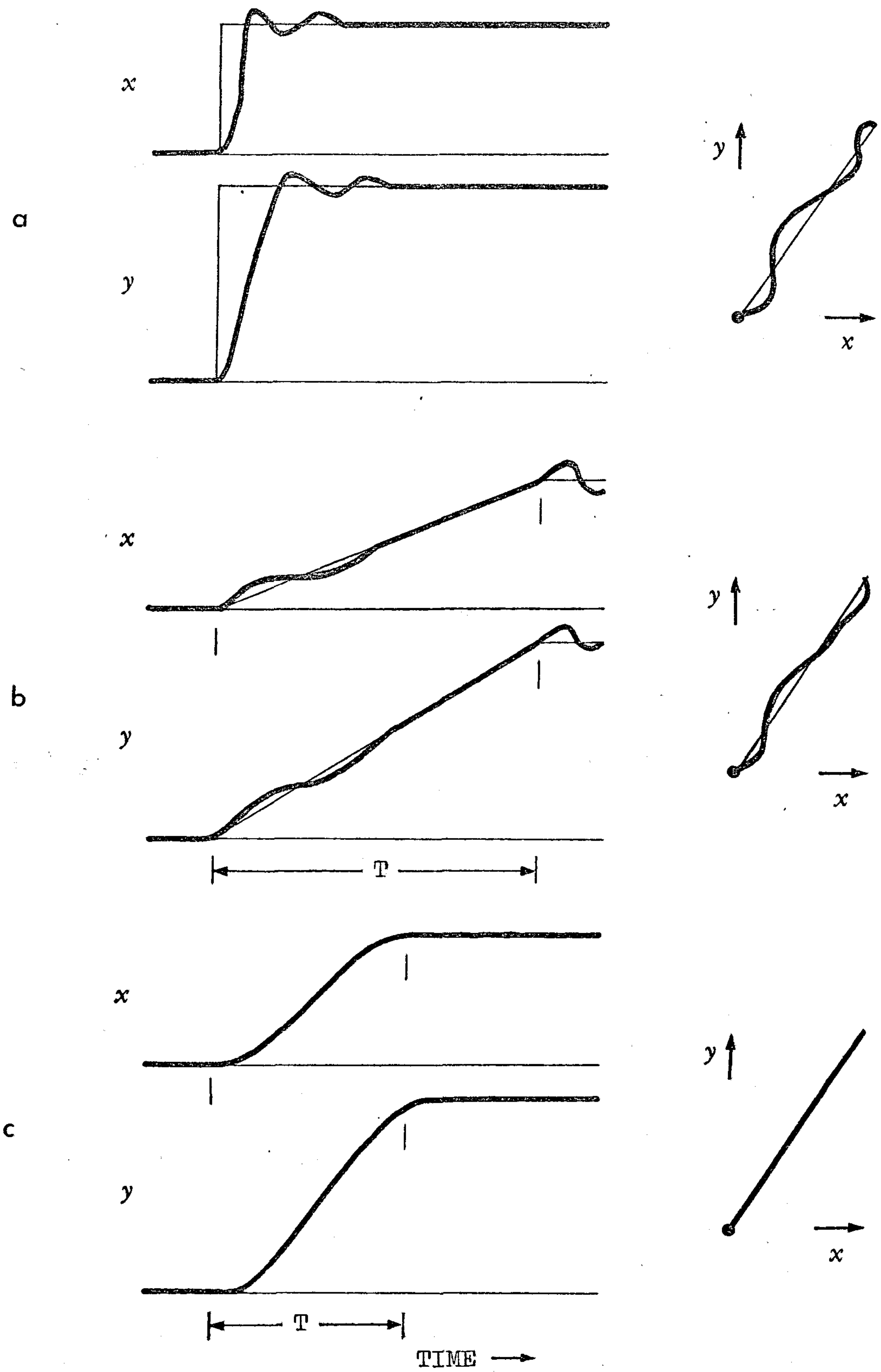


Fig. 34 Examples of vector lines produced by the x and y components of input voltages with different transient waveforms. Thin line: Electronic input. Thick line: Mechanical response.

4.6 Formats of tapes

Three types of tape with the following formats are required for plotting a set of vectors.

Tape S

		SECTION 1		← 2 →		← 3 →		---
255* START	–	x	y	x	y	x	y	
MEMORY ADDR	0	1	2	3	4	5	6	

Each section corresponds to each vector in the set. Binary numbers between 0* and 254* should be used for the values of x and y (see Fig. 27).

Tape T

			← SECTION 1 →								---
255* START	–	–	Ax	Ay	X	Y	–	–	–	–	

A_x and A_y represent memory addresses at which the values of x and y in Tape S are written. X and Y represent the position of the origin of the vector with reference to a certain point on the diagram (see Fig. 25). Binary numbers between 2* and 254* should be used for A_x and A_y, and 0* and 254* for X and Y.

The order of sections in this tape is not necessarily the same as that in Tape S. The order of sections in Tape S can be re-arranged for Tape T, so that the vector plotting becomes most efficient.

Tape U

	← SECTION 1 →									← 2 ---
"255* START	x	y	X	Y	–	–	–	–	–	

A tape in this format can be obtained automatically by feeding Tapes S and T into the data editing unit (chapter 2). When Tape U is fed into the vector plotting unit, through a tape-reader, the final vector diagram is obtained.

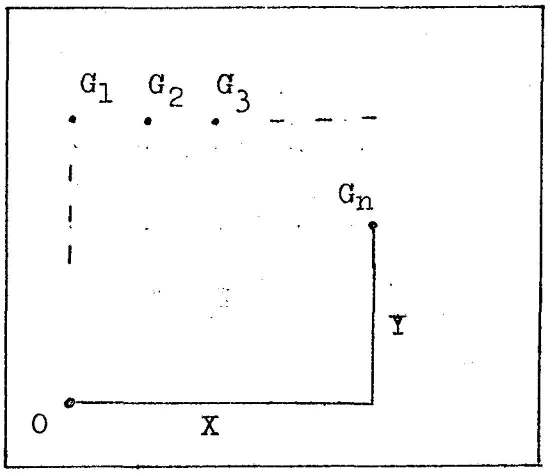
For a fixed format of a set of vector diagrams, the same tape in the format of Tape T can be used repeatedly, while Tape S has to be prepared for each set of vector data. The procedure of designing Tape T is as follows:-

(1) Decide the positions of grids, G_1, G_2 ... G_n, on each of which a vector is plotted on a sheet of paper, as shown in Fig. 35a.

(2) Decide the certain reference point, O, from which the position of each grid, G, is determined by X and Y.

(3) Make a table in the format shown in Fig. 35b. A_x and A_y are the memory addresses at which the values of x and y in Tape S is written. Then Tape T can be made from this table.

a



b

Grid No	A_x	A_y	X	Y
G_1				
G_2				
⋮				
G_n				

Fig. 35 Some procedure for making Tape T: (a) Example of grids. (b) Example of a table.

Note, the memory addresses where the x and y of each section of Tape T is written can be found by looking at the order of the sections and address numbers. For example,

A_x (section 1) = 2
A_y (section 1) = 3
A_x (section 2) = 4
A_y (section 2) = 5
.....

Remember, the order of sections in Tape T is not necessarily the same as the order of the grid numbers in the table in Fig. 37. The order can be re-arranged so that the vector plotting speed becomes maximum.

Fig. 36 shows an example of the order of vector plotting. The pen of the plotter moves from START to END through the shortest distance (top of Fig. 36), although the pen is lifted from the surface of the paper during each transit (bottom of Fig. 36). The pen travels at a speed of 1.3 vectors per second.

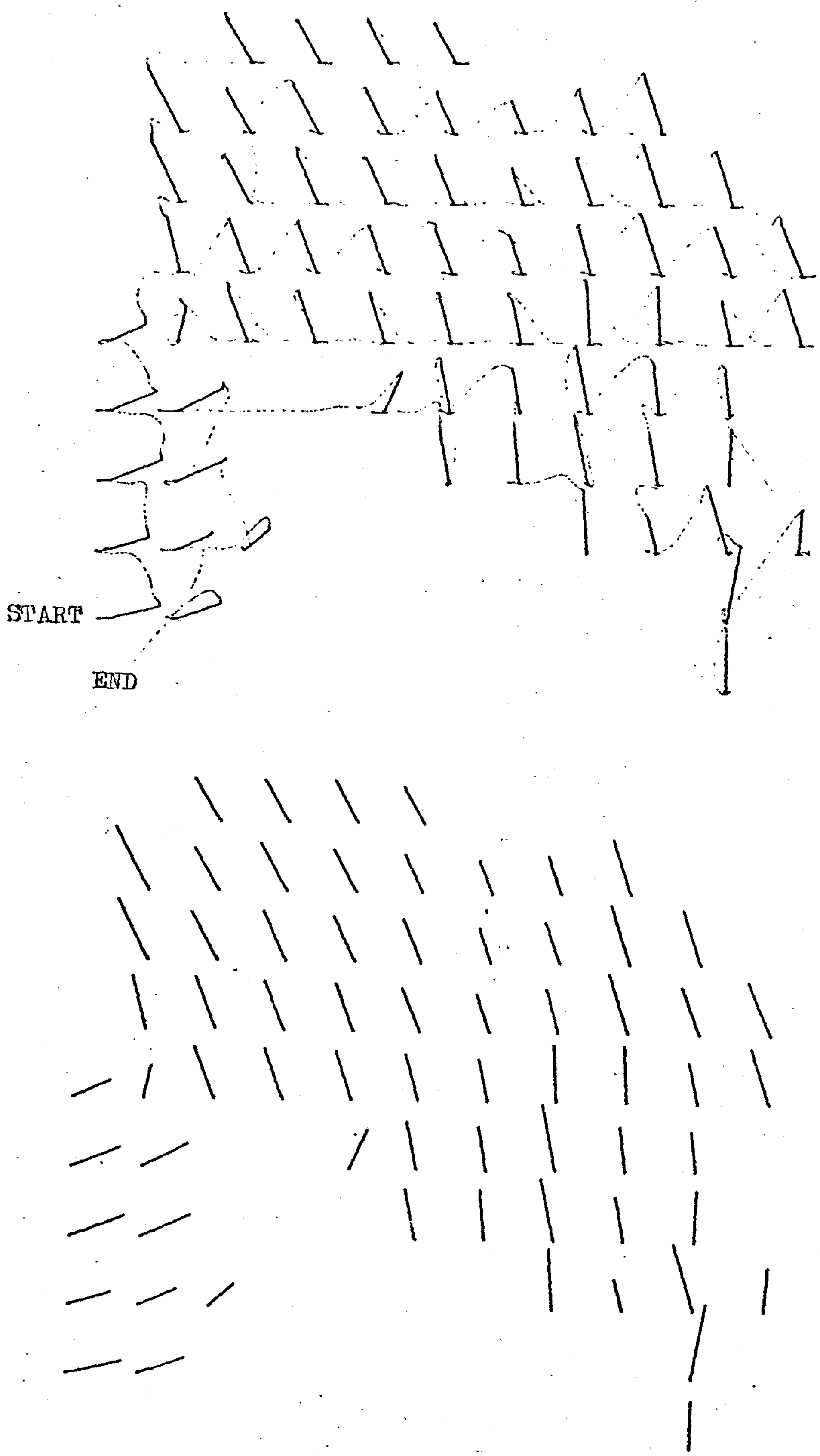


Fig. 36 Example of the order of plotting a set of vectors.
Top: Diagram drawn without the pen-lift control, in order to show the movement of the pen.
Bottom: Diagram obtained in a normal operation.

5. OPERATIONS AND OPERATING PROCEDURE

Since the meteorological input data processing system is versatile, its operations are explained by taking an example. Fig. 37 shows an example of a typical operation.

The first aim of this operation is to produce Tape S which is used for the dynamic computation of the surge equations, through the input memory (Ref. 2). The second aim is to display the contents of Tape S, which is a vector quantity, as a set of vector diagrams, so that the computation can be checked before it is carried on further.

The original input data can be in any form and in any media (e.g. data of the atmospheric pressure field represented by a set of isobar maps). On the other hand, the input memory works most efficiently (a fast speed with a simple circuit) with data given in the form of 8-bit binary code through a punched tape-reader (which is a provisional arrangement, and can be replaced by a magnetic tape and tape-reader). Therefore, the original input data is first converted into an 8-bit binary coded tape (Tape P in this example), and the same code is used throughout this data processing. Such a conversion of the input data is carried out, for example, by the keyboard in this system (this keyboard generates the binary code directly).

In Fig. 37, Tape Q is used for re-arranging the data on Tape P, and at the same time, for combining the data on Tape Q itself with the data on Tape P. The edited data on Tape R enters into the computing unit, BD2, and the computed result is recorded on Tape S.

In order to display the data on Tape S in the form of a set of vector diagrams, this is written into the memory, then the memory is read with Tape T by which the instruction needed for the vector diagrams is given. The output of the memory is recorded on Tape U by which the vector diagrams are produced through the vector circuit, BD33, and the XY-plotter. For a repeated operation in the same format, Tapes Q and R are used repeatedly without changing their contents. The contents of Tapes P, R, S and U change for each set of data, they are kept as records of the operation.

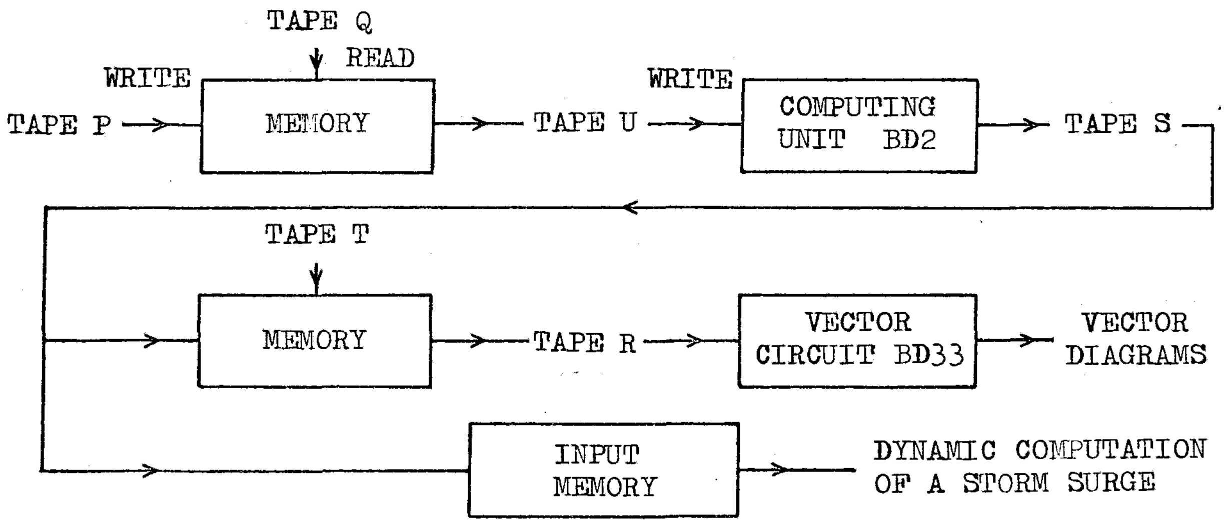


Fig. 37 Example of the flow chart of a typical operation.

Elementary operations involved in this example are:-

Copying of a tape

Editing of data

Computing of data

Displaying of data

and uses the form of tape as a media. In fact, this system has been designed for carrying out such operations in a combination, specially for meteorological data related to storm surge analyses.

The operating procedure of the system is explained by dividing it into several fundamental sub-operations. Fig. 38 shows the controls of the system which relate to the meteorological input data processing. The abbreviations shown in the figure will be used for referring to the controls. For example,

(MP) MC means 'control MC on the main control panel'.

Tape-reader (TR)

The tape-reader can read a tape in the continuous mode (500 w/s) or step-by-step mode (500 w/s max). The selection of the modes is carried out automatically when a certain operation mode is selected by other controls. In some operation modes, the tape is driven in the mixed mode (continuous and step-by-step), in order to obtain an optimum overall speed. It is recommended that the tape is passed through the FELT PAD to stop mechanical vibrations of the tape, particularly when it is driven in the mixed mode. Before a tape is driven, it should be locked by (TR)LK.

A tape is driven only when both the tape-reader motor and clutch are activated by the electronic circuit whose power is supplied from the main control cabinet. The motor alone can be started for preparation, by setting (TR)F-B to F.

(TR)IM-GE should be set to GE all the time, except when the tape-reader is used for the input memory. (TR)START is irrelevant to the operations described in this chapter. <u>(TR)F-B is most frequently used.</u>

Tape-punch (TP)

The tape-punch can punch a tape in the continuous mode (75 w/s) or step-by-step mode (75 w/s max). However, generally the latter is used, and the former is used only for 'skipping' a tape (advancing a tape with its tape-feeding holes, without punching words).

A tape can be skipped by pressing (TP)SK or (KB)SK.

The motor of the tape-punch must be started before punching or skipping is carried out. The motor starts when (TP)RED is pressed, and stops when (TP)GREEN is pressed. It is recommended that the time when the motor runs is kept to a minimum.

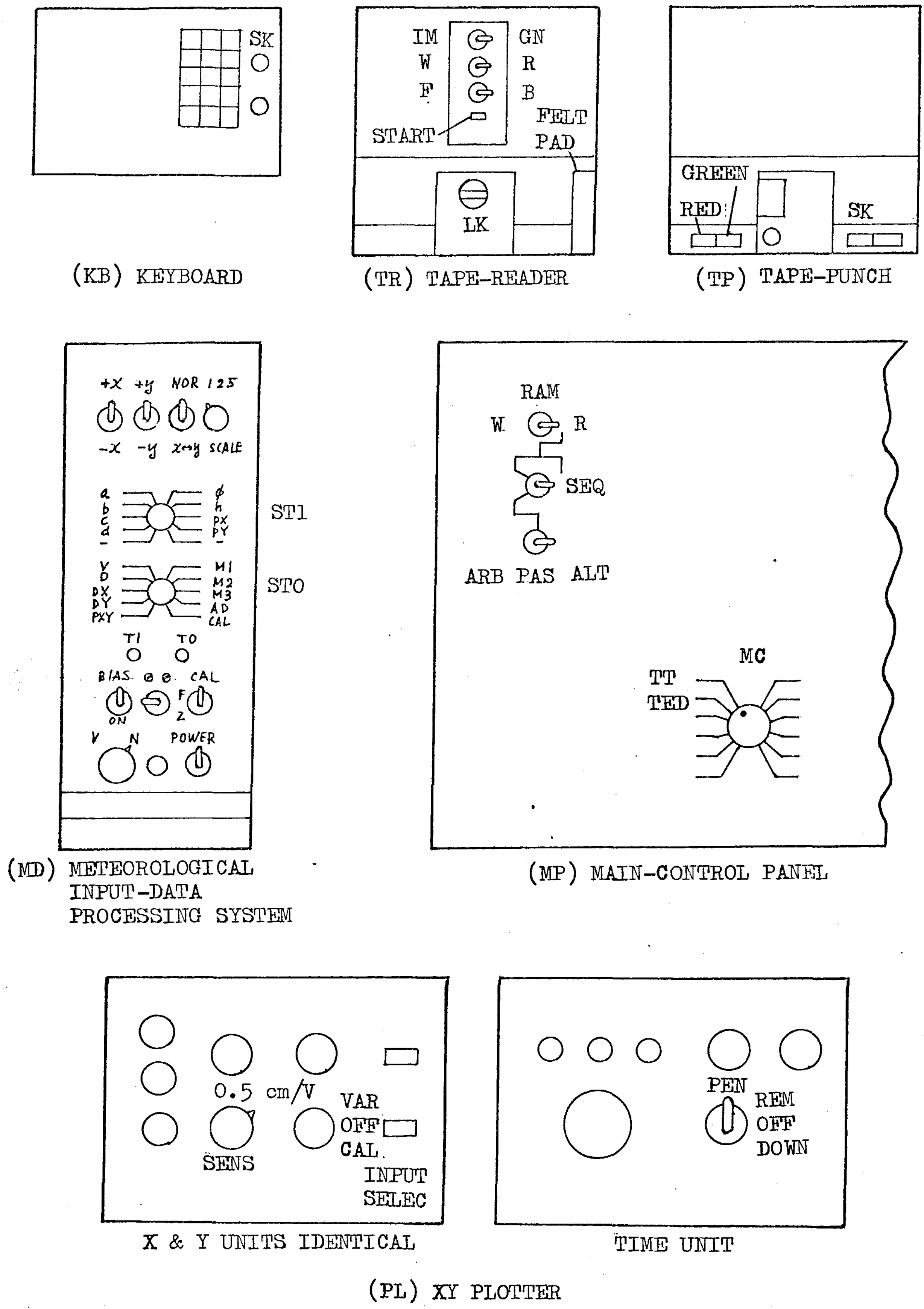


Fig. 38 Controls related to the meteorological input data processing system.

A tape can be copied in two ways: the direct copying from an original tape, and through the memory. The former is generally used, and the latter for special cases where the original tape, or the tape-reader is not available when the tape-punch is available.

1 Copying a tape directly

Set a plain tape on (TP)
Set an original tape on (TR)

(MP)MC	to	TT
(MP)RAM	to	R
(MP)ADR	to	PAS
(TR)W	to	R
(TR)F	to	F
(KB)MS		Press

Then the copied tape will be obtained.

2 Copying a tape through the memory

Write an original tape into the memory (see 3)
Read the memory in SEQ mode (see 4)

3 Writing data into the memory

Set a tape containing the data on (TR)

(MP)MC	to	TT
(MP)RAM	to	W
(TR)START		Press
(MP)RAM	to	R

Then the data will be written into the memory.

Note, the written data can be checked by reading it in SEQ mode (see 4). The tape obtained should be the same as the original.

The reading of the memory can be carried out in three different ways:

SEQ mode	to read the memory in the same order as when it was written, or sequentially reading,
ADR mode	to read the memory in the order specified by the second tape,
ALT mode	to read the memory in the order specified by the second tape, and at the same time, data on the second tape is mixed with the data on the first tape.

See page 5 for examples of formats of the above three modes.

Important: For operations 1 to 7, set (MD)V to N. For 8 only, set (MD)V to V. If (MD) is disconnected from (MP), (MP)MPD to OFF, and if (MD) is connected (MP)MPD to ON. Note, (MP)MPD is on the rear panel of (MP).

4 Reading the memory in SEQ mode

Set a plain tape on (TR)
(MP)MC to TT
(MP)SEQ to Left
(MP)ADR to PASS
Set a tape with START CODE only on (TR)
(TR)F to F
(KB)MS Press
Then the data in the memory will be punched on the tape.

5 Reading the memory in ADR mode

The same as 4, but
(MP)ADR to ADR
Set a tape in format B on (TR)

6 Reading the memory in ALT mode

The same as 4, but
(MD)ADR to ALT
Set a tape in format C on (TR)

7 Computing of data

Set the computing unit, BD2, to the required condition (see page 21 for an example). Check the scaling setting (see Table 12). Values at the various stages of computation can be sampled throughout by setting (MD)STO or (MD)ST1, and the sampled values can be recorded on a tape or monitored through (MD)TO or (MD)T1. For recording on a tape:-

Set a plain tape on (TP)
Write the input data into the memory
Read the memory in ALT mode with an appropriate tape
(see page 17 for an example)

8 Plotting vectors

A vector quantity in any stage of data handling in this system can be displayed on a set of vector diagrams, by using BD33 and an XY plotter. (The display of a scalar quantity is not explained in this paper).

Connect (MD) to (MP)
Connect (PL) to (MD)
(MD)POWER to ON
(PL)POWER to ON
(MD)V to V
(PL)SENS to 0.5 cm/s
(PL)RANGE to VAR
(MD)STO of ST1 to an appropriate position, depending on the required data
(MD)SCALE to 1, 2 or 5
(MD) three top-left switches to appropriate positions (see page 53)
Set a tape in format of Tape U on (TR) (see page 62)
(TR)F to F
Then a vector diagram will be obtained on (PL)

6. EXAMPLES OF OUTPUT

Some examples of output of the meteorological input data processing system which were finally displayed by the vector plotting unit are demonstrated.

The application of the system to a practical project is shown in a separate paper (Ref. 3).

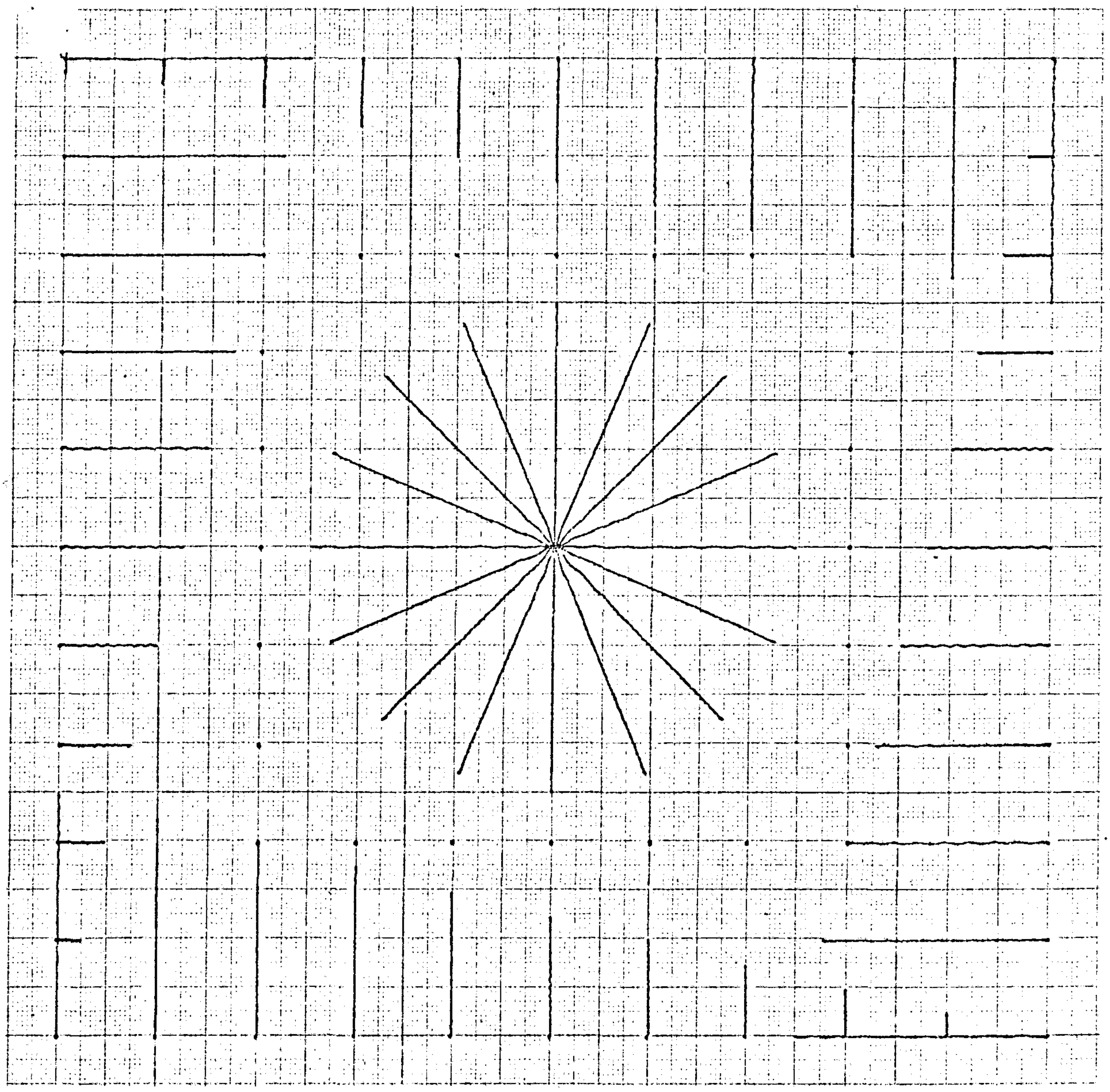


Fig. 39 Test pattern for examining the accuracy of the plotting. The input is a numerical table shown in Appendix 1. The star in the centre indicates the accuracy of angles (every 22.5°). The lines around the star indicate the accuracy at the length of lines and their positions on the graph paper (intended to be the multiples of 0.5 mm).

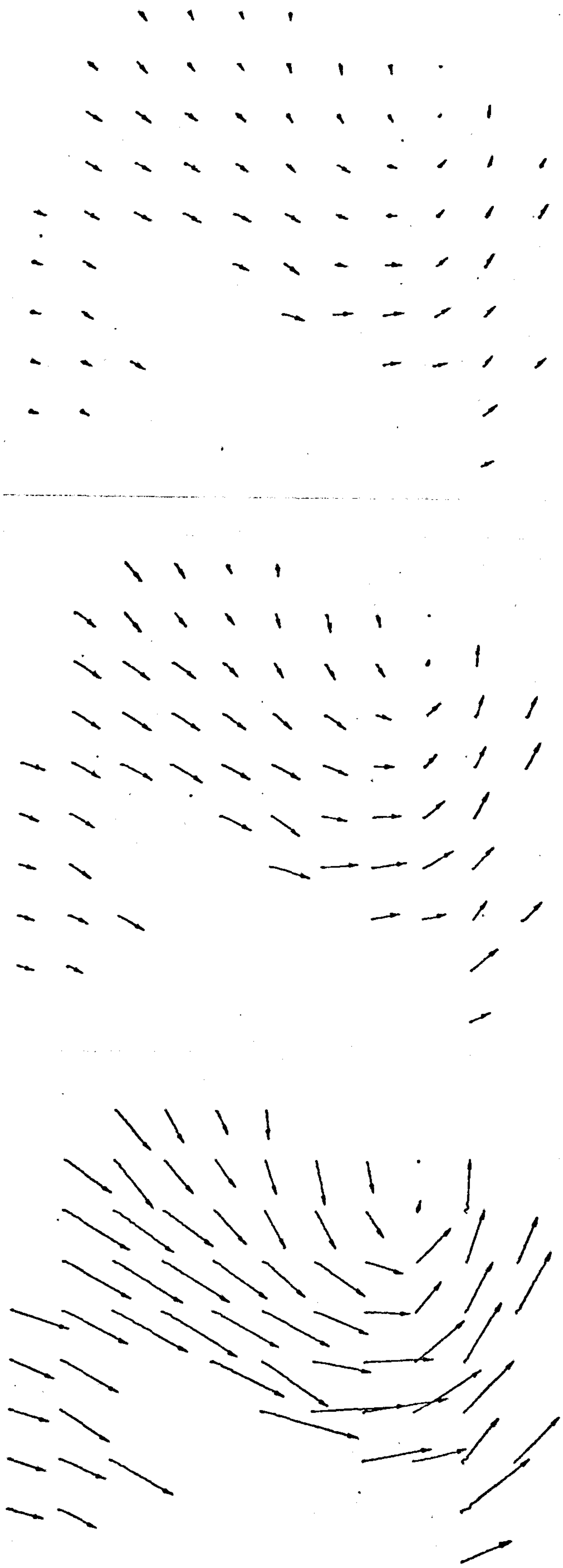


Fig. 40 Vector diagrams with different magnitude for vectors. The magnitude can be controlled by the circuit, without changing the input data. Note, the dimensions of the grids have not changed.

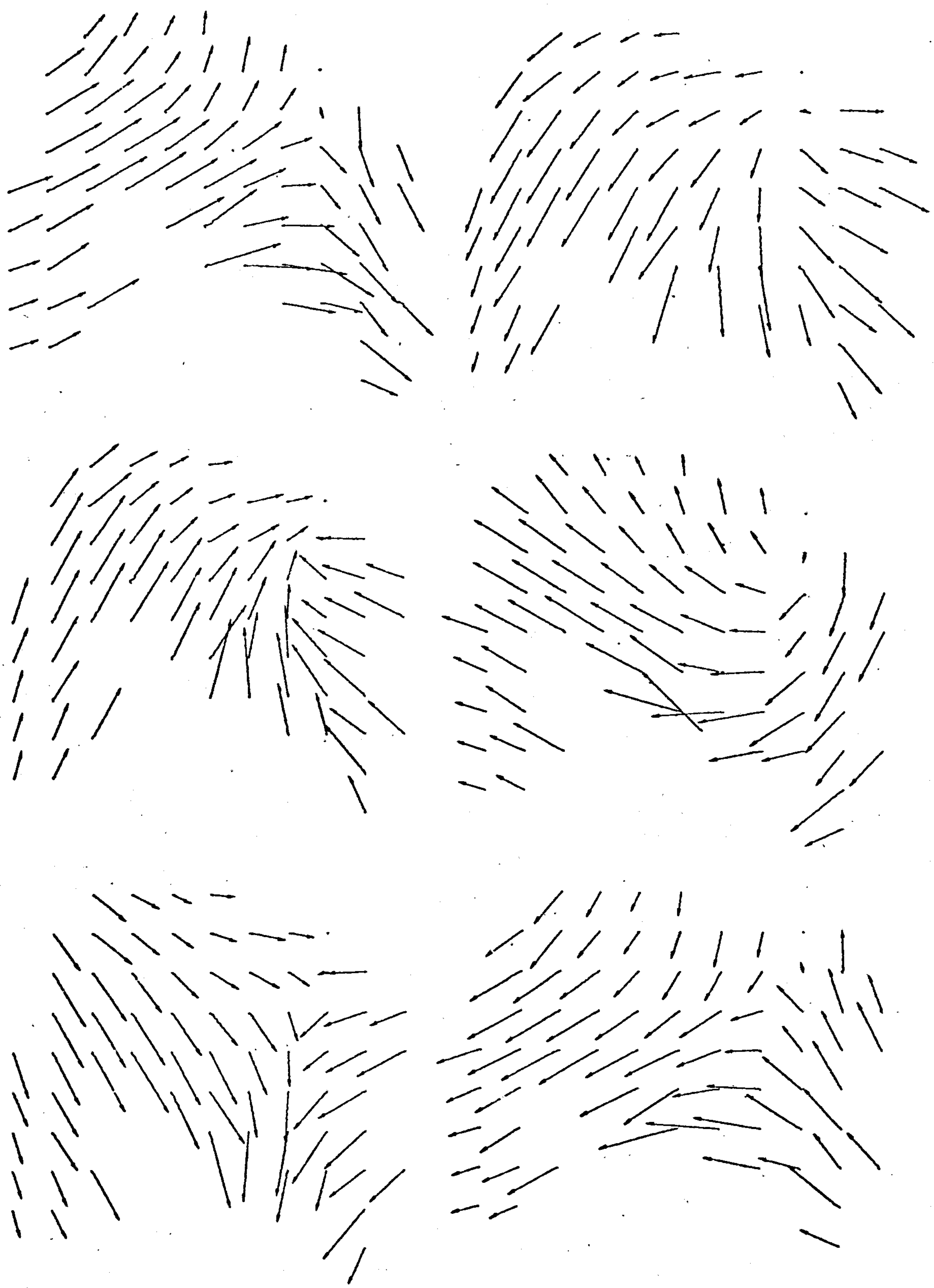


Fig. 41 Vector diagrams with different reference angles for the same input data. These variations can be made by changing the signs of x and/or y components of each vector (see page 54).

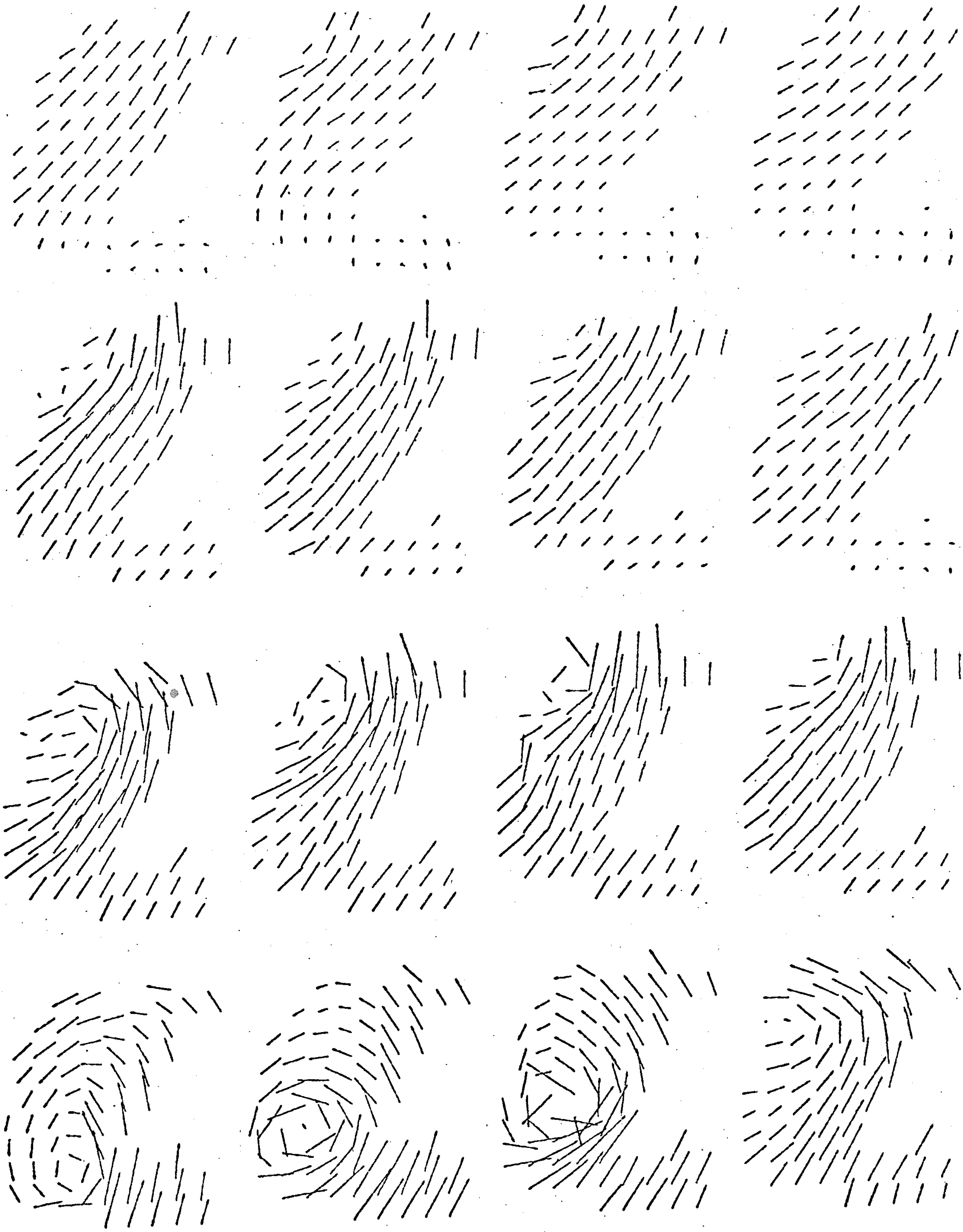
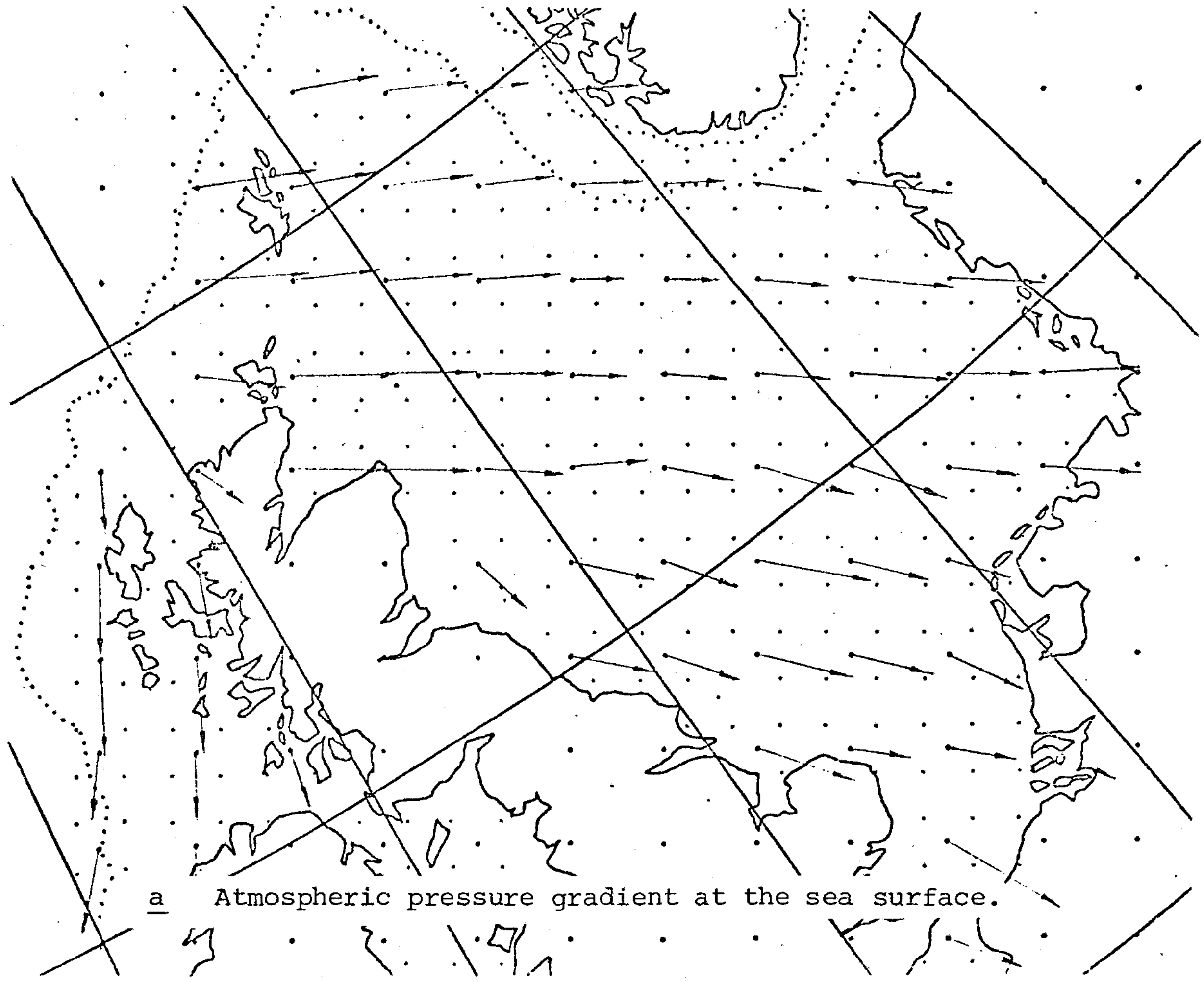
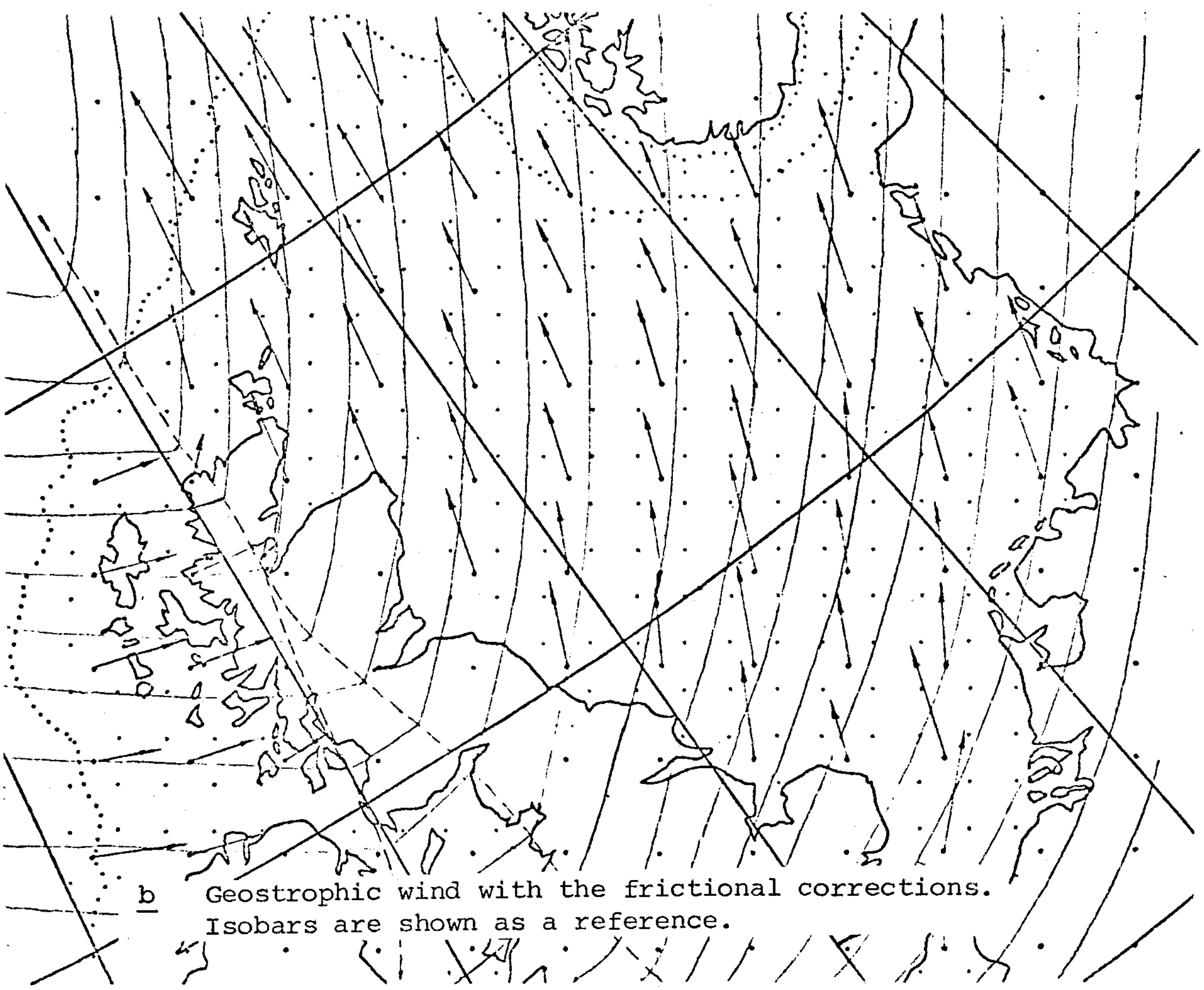


Fig. 42 Example of a set of sequential vector diagrams. 3-hourly samples of the geostrophic wind field, computed from its atmospheric pressure field, by the meteorological input data processing system.

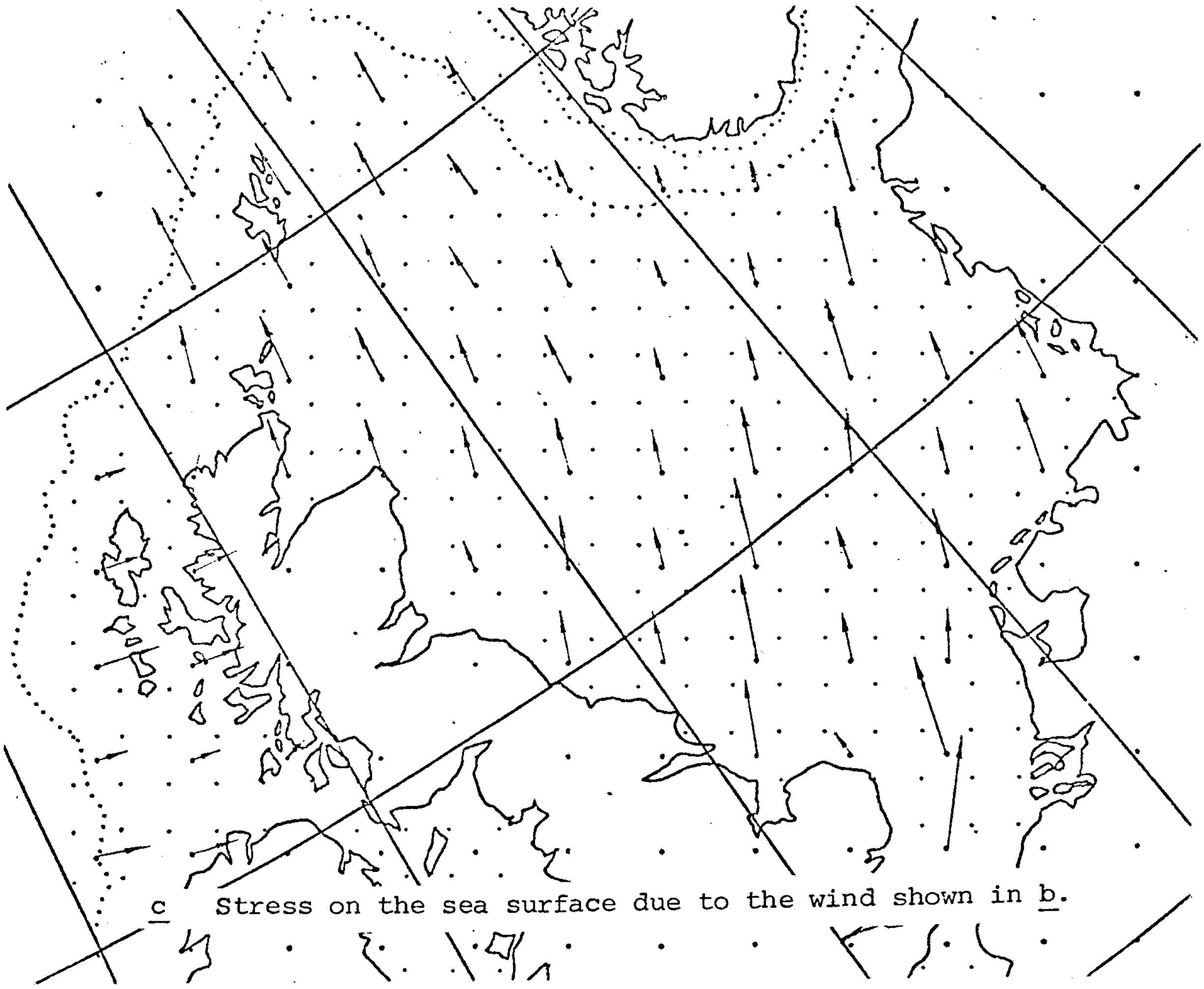


a Atmospheric pressure gradient at the sea surface.

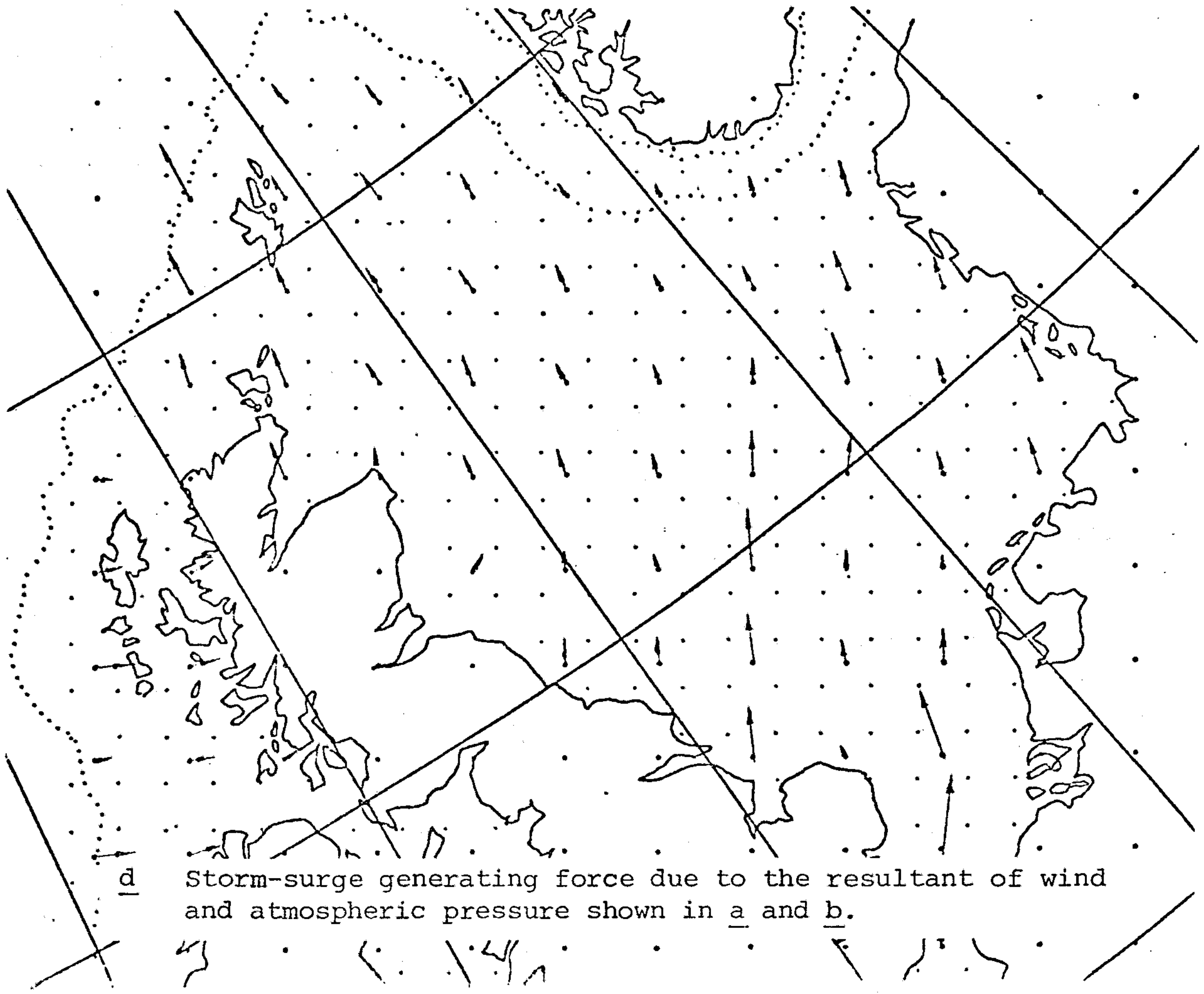


b Geostrophic wind with the frictional corrections. Isobars are shown as a reference.

Fig. 43 Examples of output applied to the North Sea. The computation scheme shown in Fig. 12 was used, by giving the values of p_a, p_b, p_c, p_d, ϕ and h_a as the input data.



c Stress on the sea surface due to the wind shown in b.



d Storm-surge generating force due to the resultant of wind and atmospheric pressure shown in a and b.

7. CONCLUSIONS

An electronic system has been developed by which meteorological input data in an arbitrary form can be converted into a form which can be processed by the new electronic model for tides and storm surges. The system has been applied to a practical project successfully, and its usefulness has been proven.

ACKNOWLEDGEMENTS

This work is part of a project commissioned by the Department of Industry and the Department of Energy. The author is grateful to Miss Kathleen Reeves-Wilkin for her help with processing data and drawing the figures in this paper.

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(4) Shellard, H.G. (1974) Proposed revision of extreme wind maps, Met. Office (in preparation).

Appendix 1 Programme for a test pattern for vector plotting. (see Fig. 39)

x	y	X	Y	–	–	–	START	x	y	X	Y	–	–	–	–
000	000	000	000	000	000	000	$\boxed{255}$	127	127	000	000	000	000	000	000
127	140	010	000	000	000	000	000	127	152	020	000	000	000	000	000
127	152	030	000	000	000	000	000	127	178	040	000	000	000	000	000
127	191	050	000	000	000	000	000	127	203	050	000	000	000	000	000
063	152	070	000	000	000	000	000	127	229	080	000	000	000	000	000
127	241	090	000	000	000	000	000	127	254	100	000	000	000	000	000
127	127	100	000	000	000	000	000	114	127	100	010	000	000	000	000
102	127	100	020	000	000	000	000	089	127	100	030	000	000	000	000
076	127	100	040	000	000	000	000	254	253	235	250	000	000	000	000
051	127	100	050	000	000	000	000	238	253	100	070	000	000	000	000
025	127	100	080	000	000	000	000	013	003	100	000	000	000	000	000
000	127	100	035	000	000	000	000	127	127	100	100	000	000	000	000
127	114	000	100	000	000	000	000	127	102	080	100	000	000	000	000
127	089	070	100	000	000	000	000	127	076	060	100	000	000	000	000
127	064	050	100	000	000	000	000	127	051	040	100	000	000	000	000
127	038	030	100	000	000	000	000	127	025	020	100	000	000	000	000
127	013	010	100	000	000	000	000	127	000	000	100	000	000	000	000
127	127	000	100	000	000	000	000	140	127	000	090	000	000	000	000
152	127	000	080	000	000	000	000	155	127	000	070	000	000	000	000
178	127	000	060	000	000	000	000	191	127	000	050	000	000	000	000
203	127	000	040	000	000	000	000	152	243	000	030	000	000	000	000
229	127	000	020	000	000	000	000	241	127	000	010	000	000	000	000
254	127	000	000	000	000	000	000	012	078	250	250	000	000	000	000
038	038	250	250	000	000	000	000	014	010	250	250	000	000	000	000
127	000	250	250	000	000	000	000	175	010	250	250	000	000	000	000
215	038	250	250	000	000	000	000	244	078	250	250	000	000	000	000
254	127	250	250	000	000	000	000	244	175	250	250	000	000	000	000
215	215	250	250	000	000	000	000	175	244	250	250	000	000	000	000
127	254	250	250	000	000	000	000	078	244	250	250	000	000	000	000
038	215	250	250	000	000	000	000	010	175	250	250	000	000	000	000
000	127	250	250	000	000	000	000	127	127	020	030	000	000	000	000
127	127	030	020	000	000	000	000	127	127	040	020	000	000	000	000
127	127	050	020	000	000	000	000	127	127	050	020	000	000	000	000
127	127	070	020	000	000	000	000	127	127	080	020	000	000	000	000
127	127	080	030	000	000	000	000	127	127	080	040	000	000	000	000
127	127	080	050	000	000	000	000	127	127	080	050	000	000	000	000
127	127	080	070	000	000	000	000	127	127	080	080	000	000	000	000
127	127	070	080	000	000	000	000	127	127	050	080	000	000	000	000
127	127	050	080	000	000	000	000	127	127	040	080	000	000	000	000
127	127	030	080	000	000	000	000	127	127	020	080	000	000	000	000
127	127	020	070	000	000	000	000	127	127	020	050	000	000	000	000
127	127	020	050	000	000	000	000	127	127	020	040	000	000	000	000

END

Appendix 2 Example of the programme for vector plotting (Tape T on page 63).

A_x	A_y	X	Y	–	–	–	–	A_x	A_y	X	Y	–	–	–	–
													START		
000	000	000	000	000	000	000	000	000	000	000	000	000	$\boxed{255}$	000	000
124	051	020	010	000	000	000	000	125	127	030	010	000	000	000	000
128	129	040	010	000	000	000	000	082	083	050	010	000	000	000	000
008	009	050	010	000	000	000	000	100	101	070	020	000	000	000	000
088	089	080	020	000	000	000	000	120	121	090	020	000	000	000	000
010	011	100	030	000	000	000	000	020	021	100	040	000	000	000	000
030	031	100	050	000	000	000	000	040	041	035	050	000	000	000	000
065	067	090	090	000	000	000	000	058	059	000	080	000	000	000	000
048	049	090	070	000	000	000	000	038	035	010	032	000	000	000	000
000	001	000	032	000	000	000	000	022	023	010	040	000	000	000	000
008	009	010	025	000	000	000	000	005	003	000	025	000	000	000	000
015	001	016	040	000	000	000	000	022	023	000	034	000	000	000	000
032	033	016	052	000	000	000	000	046	043	015	002	000	000	000	000
040	041	015	016	000	000	000	000	000	001	015	025	000	000	000	000
008	009	080	100	000	000	000	000	015	017	070	110	000	000	000	000
006	007	070	036	000	000	000	000	052	053	005	025	000	000	000	000
054	055	070	080	000	000	000	000	044	045	070	070	000	000	000	000
034	035	070	050	000	000	000	000	024	025	070	050	000	000	000	000
014	015	025	040	000	000	000	000	004	005	070	030	000	000	000	000
044	045	055	020	000	000	000	000	002	003	060	030	000	000	000	000
012	013	050	040	000	000	000	000	022	023	050	050	000	000	000	000
032	033	050	050	000	000	000	000	042	043	050	025	000	000	000	000
052	049	050	080	000	000	000	000	050	051	050	090	000	000	000	000
000	001	055	100	000	000	000	000	078	079	060	110	000	000	000	000
118	119	050	100	000	000	000	000	115	117	040	100	000	000	000	000
122	123	030	110	000	000	000	000	045	047	010	100	000	000	000	000
112	049	020	035	000	000	000	000	114	115	030	100	000	000	000	000
102	103	030	025	000	000	000	000	040	105	040	000	000	000	000	000
105	107	050	000	000	000	000	000	095	097	050	080	000	000	000	000
024	025	040	080	000	000	000	000	092	093	030	080	000	000	000	000
020	021	040	070	000	000	000	000	085	087	050	070	000	000	000	000
075	077	050	050	000	000	000	000	074	075	040	050	000	000	000	000
050	051	050	050	000	000	000	000	090	091	050	020	000	000	000	000
134	135	040	020	000	000	000	000	135	137	030	030	000	000	000	000
132	133	030	020	000	000	000	000	130	131	020	020	000	000	000	000
															END

Appendix 3 Arrow-drawing circuit*

The vector plotting unit described in chapter 4 draws a set of vectors, but without the arrow at the top of each vector. Since the origin of each vector is on a grid, and all the grids are regularly arranged, the direction of each vector can, in principle, be found without its arrow. In practice, however, this is not always easy, particularly when vectors are very small or very large. For the first set of vector diagrams, each arrow was added manually with the aid of a special stencil.

The electronic circuit described in this chapter offers the automatic drawing of a set of vectors with arrows, by adding this circuit to the original circuit with minor modifications (only two resistors) to the latter.

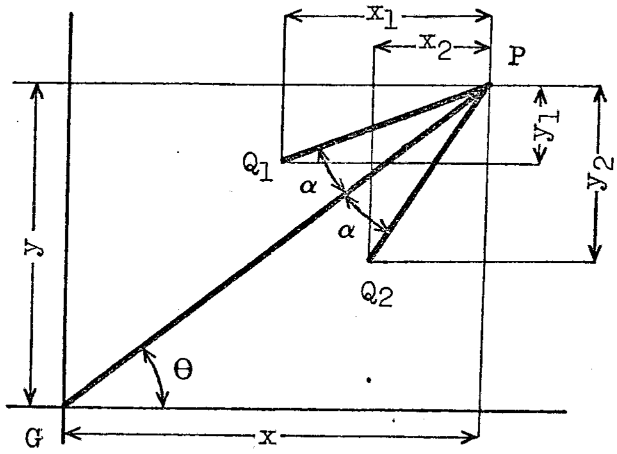

Fig. A1 Geometrical relationship between a vector and its arrow. G: origin for x and y. P: origin for x_1, y_1, x_2 and y_2. $\overline{PQ_1} = \overline{PQ_2} = A$.

Fig. A1 shows the geometrical relationship between a vector and its arrow. It is assumed that the arrow is drawn symmetrical to the line representing the vector, and A and α are constant throughout all the arrows, independent from the direction, θ, and magnitude, $\overline{GP}$, of the vector. Note the origin, P, of the coordinates for the arrow are chosen differently from the origin, G, of coordinates for the vector, in order to simplify the expressions. Although x and y are bipolar, their absolute values are only interesting in this consideration.

* This circuit was originally intended to add to the circuit shown in Fig. 30, but has not been completed at the time of writing this paper. Therefore its principle and block diagram only are shown in this appendix.

Then,

$$\left.\begin{aligned} x_1 &= A\cos(180^\circ - \alpha + \theta) = A(c_1x - s_1y)/\sqrt{x^2 + y^2} \\ y_1 &= A\sin(180^\circ - \alpha + \theta) = A(s_1x + c_1y)/\sqrt{x^2 + y^2} \\ x_2 &= A\cos(180^\circ + \alpha + \theta) = A(c_2x - s_2y)/\sqrt{x^2 + y^2} \\ y_2 &= A\sin(180^\circ + \alpha + \theta) = A(s_2x + c_2y)/\sqrt{x^2 + y^2} \end{aligned}\right\} \quad (A1)$$

where
$$\begin{aligned} c_1 &= \cos(180^\circ - \alpha) \\ s_1 &= \sin(180^\circ - \alpha) \\ c_2 &= \cos(180^\circ + \alpha) \\ s_2 &= \sin(180^\circ + \alpha) \end{aligned}$$

If $\alpha = 20^\circ$ is chosen, for instance,

$$\begin{aligned} c_1 &= -0.94 \\ s_1 &= +0.34 \\ c_2 &= -0.94 \\ s_2 &= -0.34 \end{aligned}$$

Therefore, two points, Q_1 and Q_2, referred to the top, P, of vector are determined by x and y, when A and α are fixed. The additional electronic circuit should be designed so that the XY-plotter pen moves, after line PG has been drawn by the original circuit, along PQ_1 and PQ_2, as shown in Fig. A2.

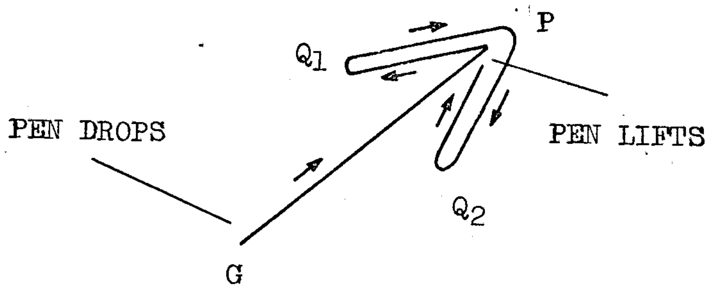

Fig. A2 Order of drawing a vector with its arrow, by the XY-plotter.

The only reason why the pen draws twice for both PQ_1 and PQ_2 is to reduce the complexity of controlling the pen lifting or dropping. The high accuracy of representing A and α is not required, since the dimensions of each arrow is small compared with its main line for a vector. However, the arrow must not change the length of the main line, i.e. x_1, y_1, x_2 and y_2 must be as near zero as possible at point P.

Fig. 53 shows the schematic diagram of the circuit by which the above-mentioned principle can be realized. Three variable input signal voltages, x, y and $\sqrt{x^2 + y^2}$ are available from the circuit, BD33 (see Fig. 15b, page 28). Voltages x_1, y_1, x_2, y_2 in equation (A1) are obtained by combining them with their coefficients c_1, c_2, s_1, s_2 by the adding/subtracting circuits, and by dividing the combined voltages by $\sqrt{x^2 + y^2}$ by the dividing circuits. The set of voltages representing (x_1, y_1) or (x_2, y_2) is obtained in order through the switching circuit. Then they are added to the output voltages of BD33 with an appropriate timing (just after the drawing of the top of a vector is completed).

Since the drawing of the arrow on the top of a vector line does not require such high precision as that for the line itself, the arrow drawing circuit does not have to be very precise.

Since the total length of an arrow is much less than the total length of an average vector line, the speed of vector plotting will not be significantly reduced by the arrow drawing.

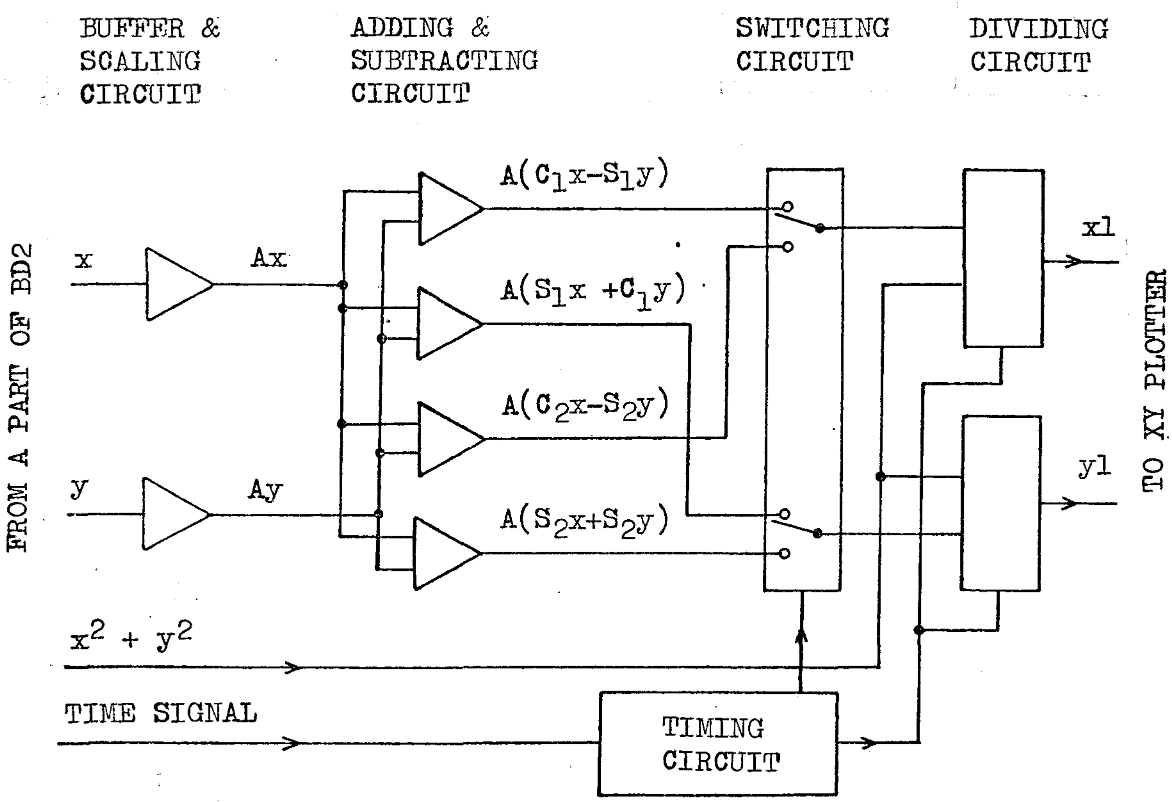

Fig. A3 Schematic diagram of the arrow drawing circuit.