PK P400023

PINSTECH/NPD-102

Description and Repair Procedure for Optical Digitizers PAC-4

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1. INTRODUCTION.

In neutron diffractometers and instruments like the triple axis neutron spectrometer installed at Pakistan Atomic Research Reactor at PINSTECH, the neutron energy is selected by diffracting a neutron beam from single crystal monochrometors. For accurate determination of the selected neutron energies, it is important to measure the diffraction angles very accurately. In typical instruments an accuracy of about 1' to 2' is required.

The triple axis spectrometer at PINSTECH employs optical coded disc digitizers to measure the angle of rotation of its various axes. The digitizers type PAC-4 are manufactured by the Institute for Research, Swierk, Warsaw, Poland.

The optical digitizer type PAC-4 is an optical analogue-to-digital converter with parallel read outs. The optical digitizer is intended for digital measurements of angular rotation of its shaft. In this application the central shaft of the digitizer is coupled to a wheel, which moves on the carriage of the respective spectrometer axes, and indicates its angular position.

2. PRINCIPLE OF OPERATION.

The schematic layout diagram of the digitizer is shown in Fig-2. The optical digitizer with coded plates ensures required accuracy with relatively simple electronic circuits.

As shown in Fig-2, light from optical lamp 7 falls on the coded discs (4, 5) through two optical prisms (6). The two coded discs are coupled to each other with a 10:1 gear ratio. The plate with fine slots is directly coupled with the central shaft (1). Light passing through the coded

discs is selected through read out hair-line slits (9) placed between the photo-diodes and the coded discs. Photo diodes (5) are placed behind each slit. The number of photo-diodes is equal to the number of coded rings on the circular coded discs. The coded rings in a coded disc are made in a photochemical manner. The concentric code rings consist of transparent and non transparent divisions Fig. 3. The rotation of the coded discs modulates the light flux which is converted by photo-diodes into electronic pulses.

In this manner digital conversion for each position of the input shaft (1) with respect to converter casing (10), is achieved.

Electronic circuitry built using integrated circuit operational amplifiers and NAND gates is housed on the printed boards (2).

3. TECHNICAL DATA.

- Angular Resolution,[1]	1:1000 on 10 turns of input shaft
- Minimum, measure-able angle :	1/5000 of full turn (2.16)
- Code :	VARTZ reflected decimal code[2]
- Counter-clock wise rotation corresponds to increase of angle of the spectrometer.	
- Fixing :	Flange
- Coupling :	Elastic
- Supply voltages for electronics circuits :	regulated + 6V ± 5% +12V ± 5% -12V ± 5%
- Supply voltages for lamps :	regulated 6V
- To enable exchange of lamps facilities are fore-seen at the housing of optical digitizer.	

4. ELECTRONIC DESIGN.

The electronic circuitry is bui t in three stages described below:-

1. Single input read out amplifier (employed with the fine disc).
2. Double input read out amplifier (employed with the course disc).
3. NAND gates for final out-puts.

Description of Read Out Amplifiers.

i) Single input amplifiers.

Schematic diagram of read out amplifier is shown in Fig-4 which also gives actual layout. The integrated circuit (IC) SN 72709 is used in the voltage operational amplifier with one input mode[3]. Input to the amplifier is given by the photo-diode IN 2175[4] which conducts according to the position of the coded disc. Normally dark current of the photo diode causes $V_{out} \simeq 6V$. In the diode conducting condition $V_{out} \simeq 0.8V$. The operational amplifier gives 'ON' condition when the input current is more than 10 μ amp, which correspond to an input of 30-50 mv. At the out-put of read-out amplifier diodes D_{13} and D_{14} (Fig-4a) are used in regenerative mode. D_{13} and D_{14} keep the mimimum and maximum out-put levels Z_1 and Z_2 at 0.8V and 5.8 volts respectively. The single input amplifier is used in disc-I.

ii) Double input amplifiers.

A double input amplifiers is used with the course coded disc (disc II), in which the conduction of odd or even diodes determines the code for parity or non-parity. The parity is important in generation of the final number using WRD codes, as described in the next section.

iii) NAND gates.

Sixteen NAND gates are used at the out-put stage to drive the coded information to the control pannel of the triple axes spectrometer.

The gates are based on the integrated circuit SN 7426[5]. This output information in the WRDC is converted in the control pannel (Board-18,19 & 20) to the decimal system and is displayed.

Electronic Layout in Digitizer.

Fig 5 and 6 show the input connector and the power distribution to the disc I and II. Fig. 7 gives the component and connection layouts of discs I and II. Fig. 8 and 9 show the electronic schematics of disc I and disc II. Fig 10 describes the wiring diagram, out-put stage of the digitizer. The combined electronics schematic diagram of the digitizer is given in Fig. 11.

5. HARTZ REFLECTED DECIMAL CODE.

The WRD Code is developed from o the reflected binary decimal (RBD) code [6] as shown in table I. The WRD code is shown in table 2. The main difference between the WRD Code and RBD Code is that the RBD Code is formed from a simple binary code, in a manner that the numbers after '7' are obtained by replacing '0' in the first colomn by '1' and reflecting back the remaining colomns of 6th and 5th rows as shown in Table 1. While, the WRD Code is formed by replacing '0' after the 4th row in first column by '1' and reflecting back the dotted box, to obtain the higher values of the decimal numbers, as shown in Table 2. In RBD Code the Ist column upto the 7th line is all 0's and the remaining 7th and 8th lines are "1". While in WRD the top half in the Ist column upto 5th row are all 0's and the lower half below 5th row are all 1's (Table-2).

A WRDC using a parity digit has been used in PAC-4. Twelve light sensitive diodes are used with disc I, which represent three digits. Ten optical diodes are employed with disc II. The diodes give inputs to five operational amplifiers, two diodes pairing together to give input to one amplifier. These 5 outputs combined with the outputs of disc I form the four output digits. Table 3 gives the WRD code as used in PAC-4.

The method of conversion in PAC-4 is such that the digit indicated, is said to be "parity" if the next higher digit is an even number, i.e. 0,2, 4,6 and 8. Similarly the digit is said to be "non parity" if the next higher digit is an odd number i.e. 1,3,5,7 and 9. The highest digit (4th digit) is always parity. A digit is read from the respective parts of Table 3, depending on the parity or non-parity labelling of the digit.

Example I.

i) Let 3517 be the reading of the four indicators displayed on the spectrometer pannel. According to Table 3 WRD Code for this reading would be as follows:-

Number	(WRD) Code.
3	0010
5	0110
1	1001
7	0011

Note: The highest digit (4th digit) is always parity. It can be seen that No 3 is the 4th digit and is a parity digit

WRD for 3 = 0010(p)

As No. 3 is an odd No WRD for 5 = 0110(np)

As No. 5 is an odd No. WRD for 1 = 1001 (np)

As No. 1 is an odd No. WRD for 7 = 0011 (np)

Example II.

ii) Let 6009 be the reading of four indicators. WRD code for this reading would be as follows:-

Number	(WRD) Code
6	1010
0	0000
0	0000
9	1000

As the 4th digit is always parity:

WRD for 6 = 1010 (p)

As No. 6 is an even No. WRD for 0 = 0000 (p)

As No. 0 is an even No. WR for 0 = 0000 (p)

As No. 0 is an even No. WRD for 9 = 1000 (p)

6. MAINTENANCE.

In case of a fault in the number indicated in the spectrometer display, the following procedure is recommended to correct the fault:

i) If no numbers are displayed, check the power supplies (both for lamps and electronic circuit).

ii) Check the bulb, if fused, replace it.

iii) If the display shows irregular sequence of numbers, first check the bulb. Its glass (face side) should not have dark traces on it. If so, replace it.

iv) If the fault is not removed, take out the bulb holder and clean the prisms in the digitizer with a clean soft cloth.

v) If the fault still persists, the decimal numbers should be converted into WRD code according to Table 1 and Table 3 as shown in examples given earlier. Check the input voltage levels on board number 18, which receives inputs from digitizers. There is one board for each digit. If the levels are according to the conversions made above, then the fault is in the digitizer.

vi) Unscrew the digitizer from the axis body. Open the casing on the input shaft-side. Hookup the power supply and measure the voltages on photo-diodes with a multimeter and see if they provide ON-OFF signals. ON condition is 30 to 50 mV. Replace the faulty diodes if any.

vii) If diodes are OK, then check the operational amplifiers outputs. Check them for ON-OFF conditions (5.8 volts and about 0.5 volts respectively). Replace the I C's if found faulty.

viii) In the last, check the output NAND gate IC and Q_1 and Q_2 transisters for parity and non parity (Fig.9).

7. FIGURE CAPTIONS.

Fig. 1. The Digitizer (New version PAC-4) Main Assembly.

Fig. 2. Convertor Layout.

Fig. 3. The digitizer coding DISC.

Fig. 4. Operational Amplifier used in Disc I and II using SN72709.

Fig. 5. The main connector.

Fig. 6. Power and signals diagram of DISCS I,II.

Fig. 7. Digitizer Electronic circuit DISCS I, II.

Fig. 8. Schematic diagram of digitizer DISC-I, (RD-4)

Fig. 9. Schematic diagram of digitizer disc-II (RD-1)

Fig.10. Input and output diagram of output I/C DISC-II.
- ICs 18-21 are SN7426
-
- ICs 19-22 have the same pin numbers as IC 18.
- Numbers on Line ends indicate IC PIN Numbers.
- Numbers 6,7,8,9,10 on lines indicate circuit pint lines on electronic Disc-II.
- Box 18-21 Numbers 3,6,8,11 on each represent output PIN Numbers of IC 18-21 going to the Digital counter.
- ICs 18-22 PIN 7 is ground and PIN 14 (dark PINs) are VCC + Ve

Fig.11 Schematic electronic diagram of digitizer PAC-4.

8. LIST OF COMPONENTS

USED WITH

DIGITIZER PAC-4, DISC I,II

S.No.	Component	Volue	Location
1.	Resistance R1 through R 24	10K 5%	Disc-I
2.	Resistance R25 " R 36	3.3M 5%	Disc-I
3.	Resistance R37 " R 48	6.8K 5%	Disc-I
4.	Resistance R49 " R 53	4.97K5%	Disc-II
5.	Resistance R54 " R 58	497K	Disc-II
6.	Resistance R59 " R 63		Disc-II
7.	Resistance R64 " R 68		Disc-II
8.	Resistance R69		Disc-II
9.	Resistance R70		Disc-II
10.	Resistance R71		Disc-II
11.	Resistance R72		Disc-II
12.	Resistance R73 & R74	8K	Disc-II
13.	Resistance R75	20K	Disc-II For Ref voltage to SN72709
14.	Resistance R76	100ohms	Disc-II Across the cap on the other side print.
15.	Resistance R77	51ohms	Disc-II
16.	Diodes D1 through D12	1N175	Disc-I Photodiodes at the input of each SN72709 (FIG.8).
17.	Diodes D13 " D24	OA202	Disc-I
18.	Diodes D25 " D36	OA202	Disc-I
19.	Diodes D37 " D41	IN2175	Disc-II Opto Electronic Photodiodes (FIG.9).
20.	Diodes D42 " D46	IN2175	Disc-II
21.	Diodes D47 " D51	OA202	Disc-II
22.	Diodes D52 " D56	OA202	Disc-II
23.	Diodes D57 " D61	OA202	Disc-II
24.	Diodes D62 " D66	OA202	Disc-II
25.	Capacitor C1	0.1 uf/6v	Disc-I
26.	Capacitor C2	0.1 uf/250v	Disc-I
27.	Capacitor C3	0.1 uf/250v	Disc-I
28.	Capacitor C4	0.1 uf/6v	Disc-I
29.	Capacitor C5	[illegible]	Disc-II Q1/Collector
30.	Capacitor C6		Disc-II Q2/Collector
31.	Capacitor C7	2.1 uf	Disc-II
32.	Capacitor C8	0.1 uf/6v	Disc-II
33.	Capacitor C9	5.MF/15v	Disc-II
34.	Capacitor C10	0.1MF/6v	Disc-II
35.	Ickts. I1-I12	SN72709	Disc-I Operational Amp
36.	Ickts. I13-I17	SN72709	Disc-II Operational Amp
37.	Ickts I18-21	SN7426	Disc-II N and Gates
38.	Ickts I22	SN7400	Disc-II N and Catip system
39.	Transistor Q-1	[illegible]	Disc-II PNP
40.	Transistor Q-2	[illegible]	Disc-II PNP

10. REFERENCES.

1. Instruction Manual 'Triple Axis Neutron Spectrometer, TKSN 400' IBJ-Swierk, POLAND.

2. 'User's Guide for the Operation of the Triple Axis-Neutron Spectrometer' TKSN-400 by Ahmad Ali, PINSTECH MPD/23, 1975.

3. Data Book for Design Engineers P-4/60 Texas Instruments Incorporated, P.O. Box 5012 - Dallas 75222 U.S.A. (1973).

4. 'Opto Electronics Devices' Data book. Texas Instruments, Incorporated P.O. Box 5012, Dallas, Texas 75222 (1975).

5. Data Book - Signetics Corporation 811-East ARQUES Avenue-Sunny Vale, Calif - 94086, U.S.A. (1974).

6. 'Engineering Electronics' by John D. Ryder, 2nd Edition, Mc Graw Hill, U.S.A. (1967).

TABLE-1. REFLECTED BINARY CODE.

Decimel Digits	COLUMNS 1	2	3	4
0	0	0	0	0
1	0	0	0	1
2	0	0	1	1
3	0	0	1	0
4	0	1	1	0
5	0	1	1	1
6	0	1	0	1
7	0	1	0	0
8	1	1	0	0
9	1	1	0	1

TABLE.2. WAPTZ REFLECTED CODE.

Decimel Digits	COLUMNS 1	2	3	4
0	0	0	0	0
1	0	0	0	1
2	0	0	1	1
3	0	0	1	0
4	0	1	1	0
5	1	1	1	0
6	1	0	1	0
7	1	0	1	1
8	1	0	0	1
9	1	0	0	0

Table 1,2 Development of Wartz Reflected code from Reflected Binary Decimel code.

Table: 3. The Wartz Reflected Decimel code used in Digitizer PAC-4.

PARITY (P) Decimel Nos.	COLUMNS 1	2	3	4
0	0	0	0	0
1	0	0	0	1
2	0	0	1	1
3	0	0	1	0
4	0	1	1	0
5	1	1	1	0
6	1	0	1	0
7	1	0	1	1
8	1	0	0	1
9	1	0	0	0

NON PARITY (N.P) COLUMNS 1	2	3	4	Decimel Nos.
1	0	0	0	0
1	0	0	1	1
1	0	1	1	2
1	0	1	0	3
1	1	1	0	4
0	1	1	0	5
0	0	1	0	6
0	0	1	1	7
0	0	0	1	8
0	0	0	0	9

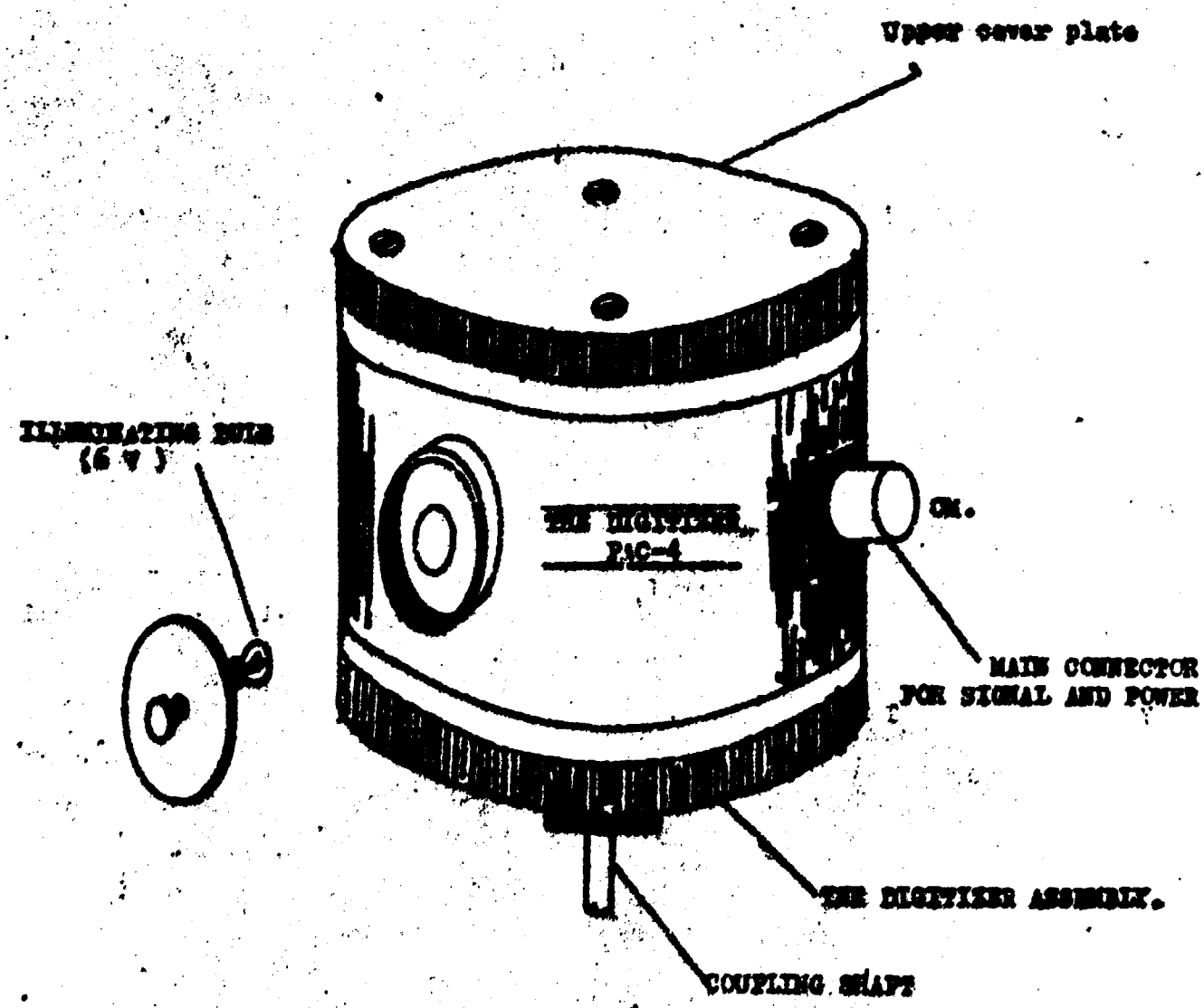


FIG-5 THE DIGITIZER (THE VERSION PIC-4) MAIN ASSEMBLY.

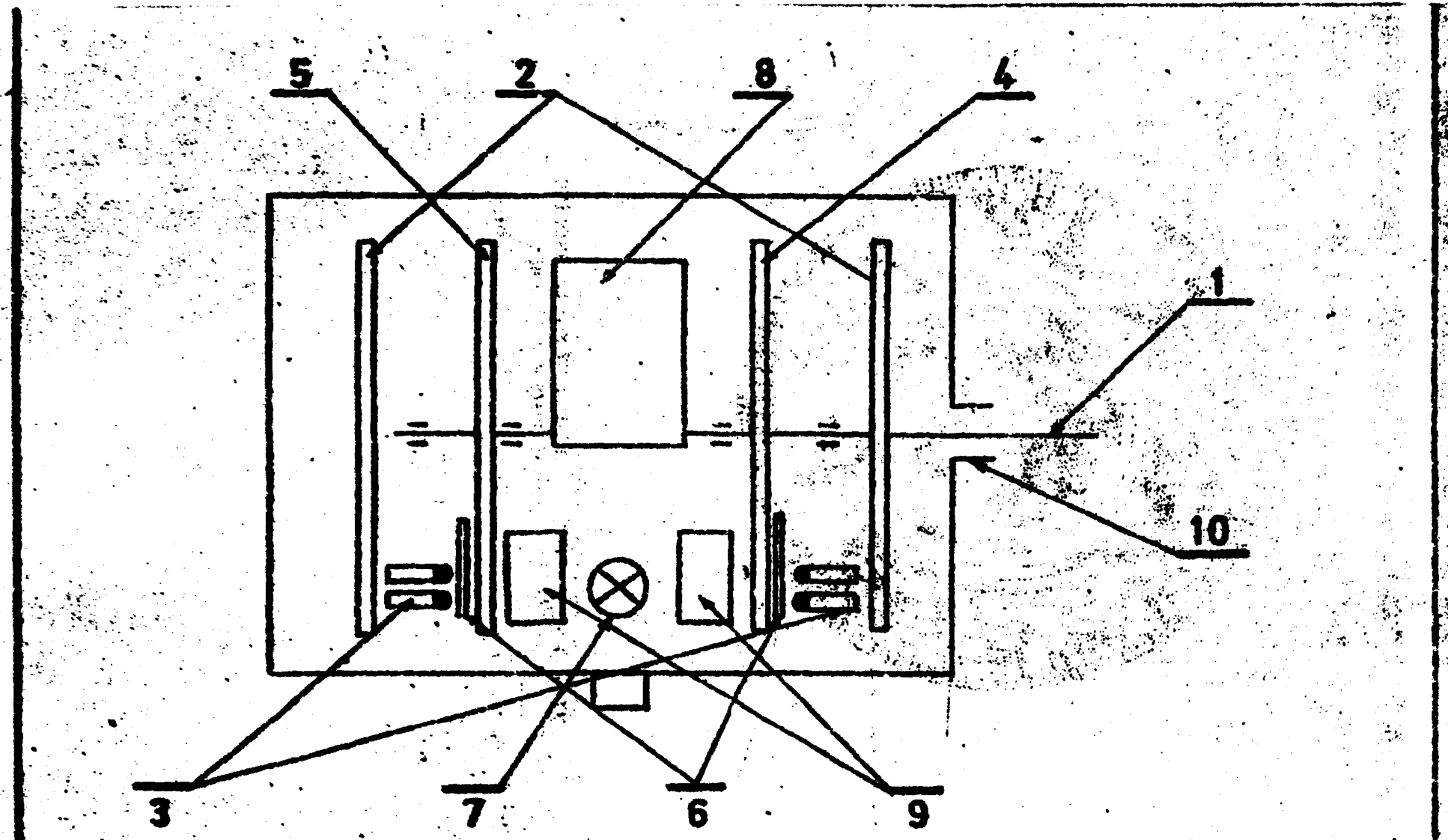


FIG. 2. CONVERTER LAYOUT

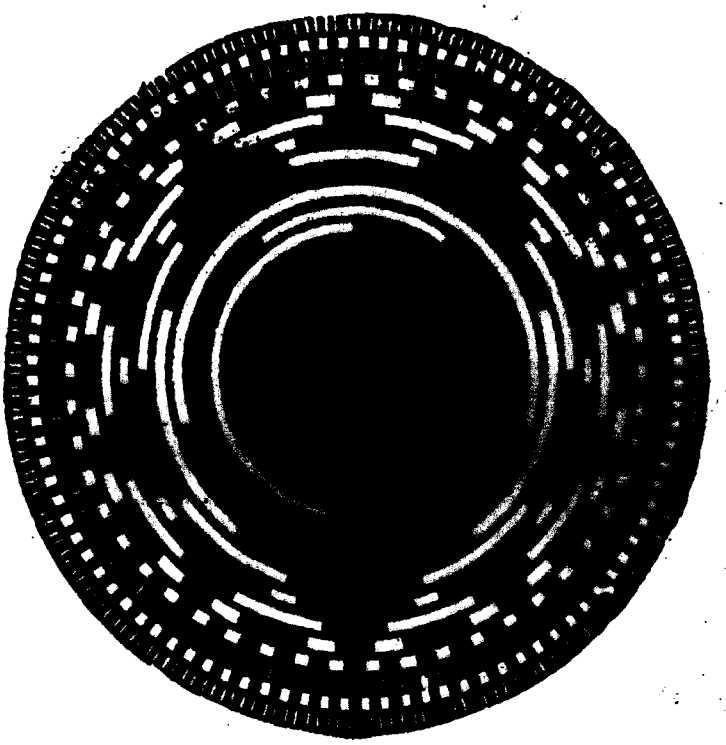
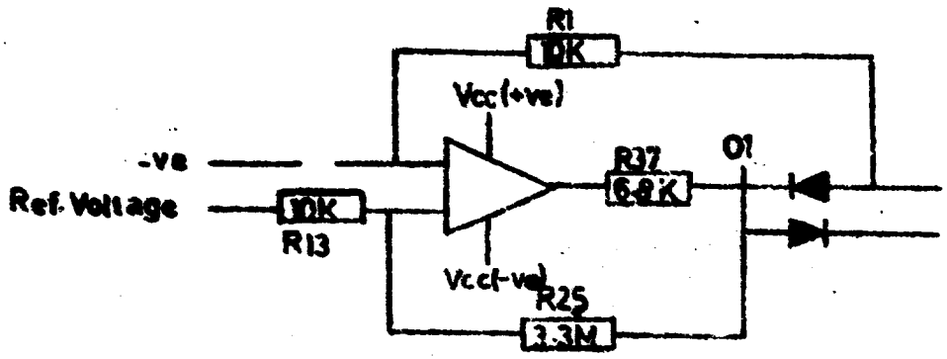
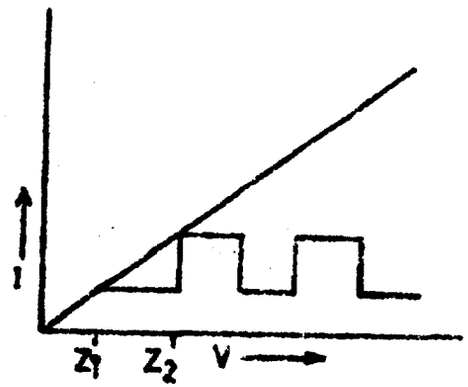


FIG- 3 THE DIGITIZER CORING MINC-4K, SHOWING TRANSPARENT AND OPAQUE POSITIONS.

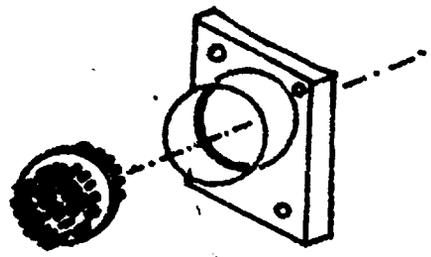


a) Circuit diagram of single stage operational amplifier

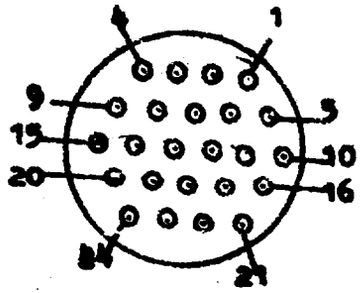


b) Digitized pulse output from op. Amp.

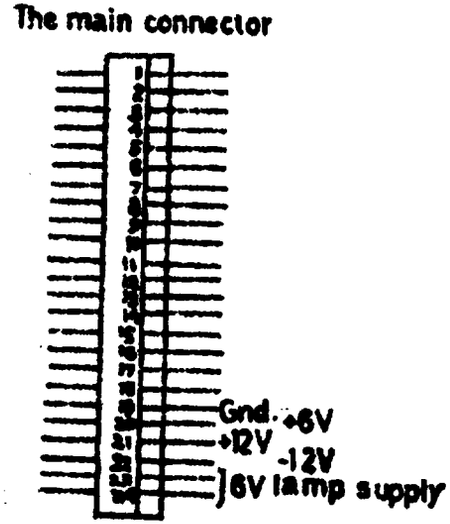
FIG-4 Operational amplifier used in Disc-I&II (SN72709)



(a)

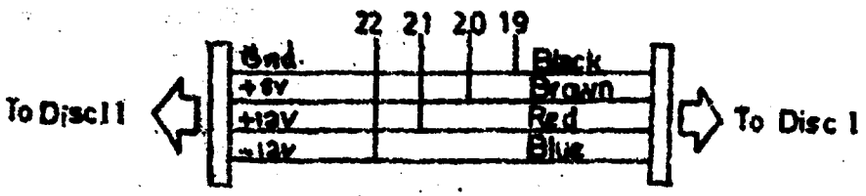


(b)

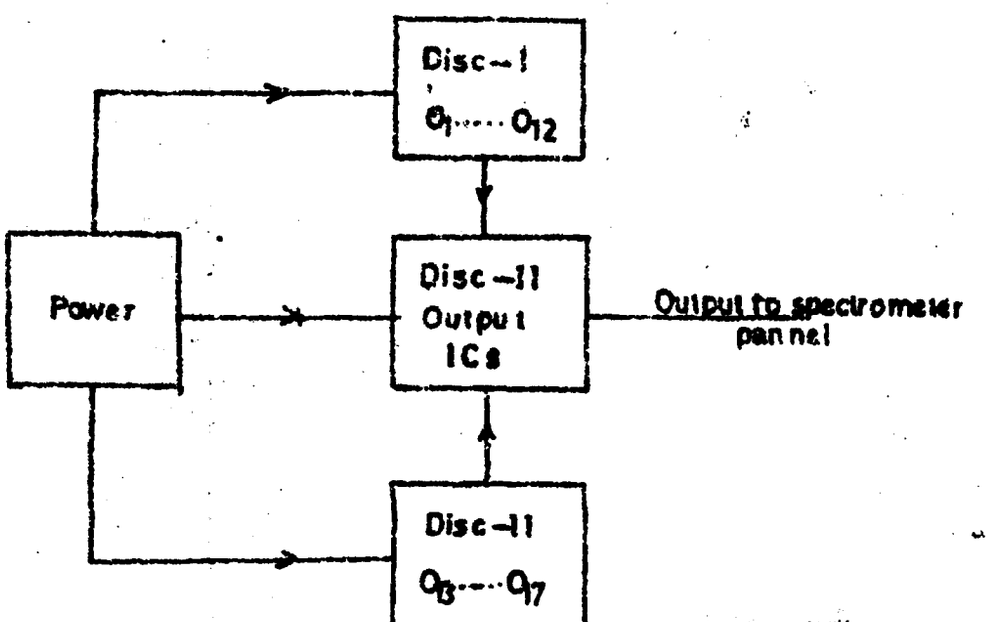


(c)

FIG-5 The main connector
a)Mechanical sketch as installed in digitizer
b)Pin Nos. diagram
c)Schematic diagram of main connector

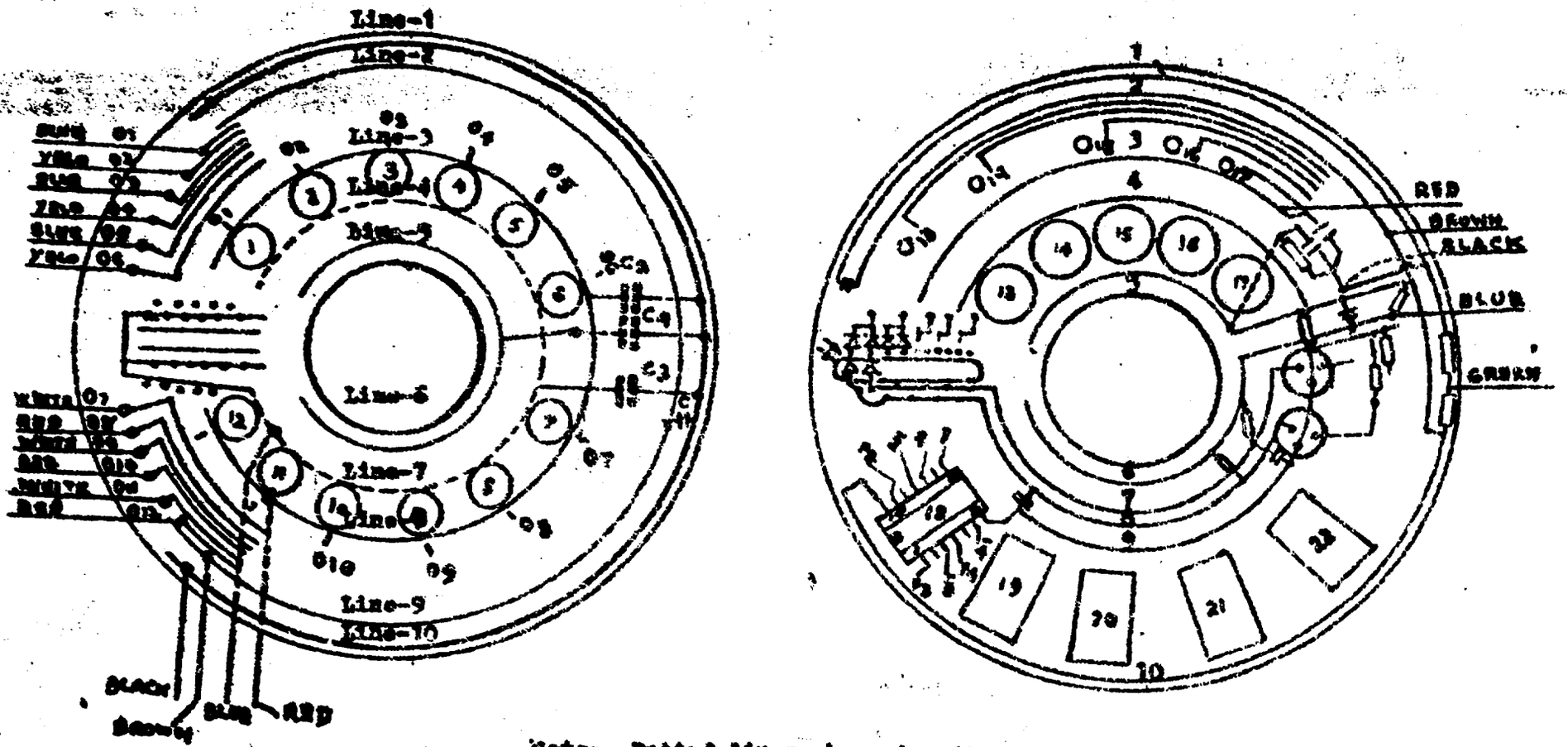


a) Power input to Discs I & II



b) Block diagram of Disc I & II interconnections

FIG-6 Power & signal inputs & outputs of Disc I & II



Note:- Dotted lines show circuit print on the bottom side of Disc I,II.
Ring lines 1-10 indicates the circuit lines on Disc-I,II.

DISC-I (PRINT SIDE)

DISC-II (COMPONENT SIDE)

FIG-4 DIAGRAMS OF DIGITIZER ELECTRONIC CIRCUIT DISCS I & II.

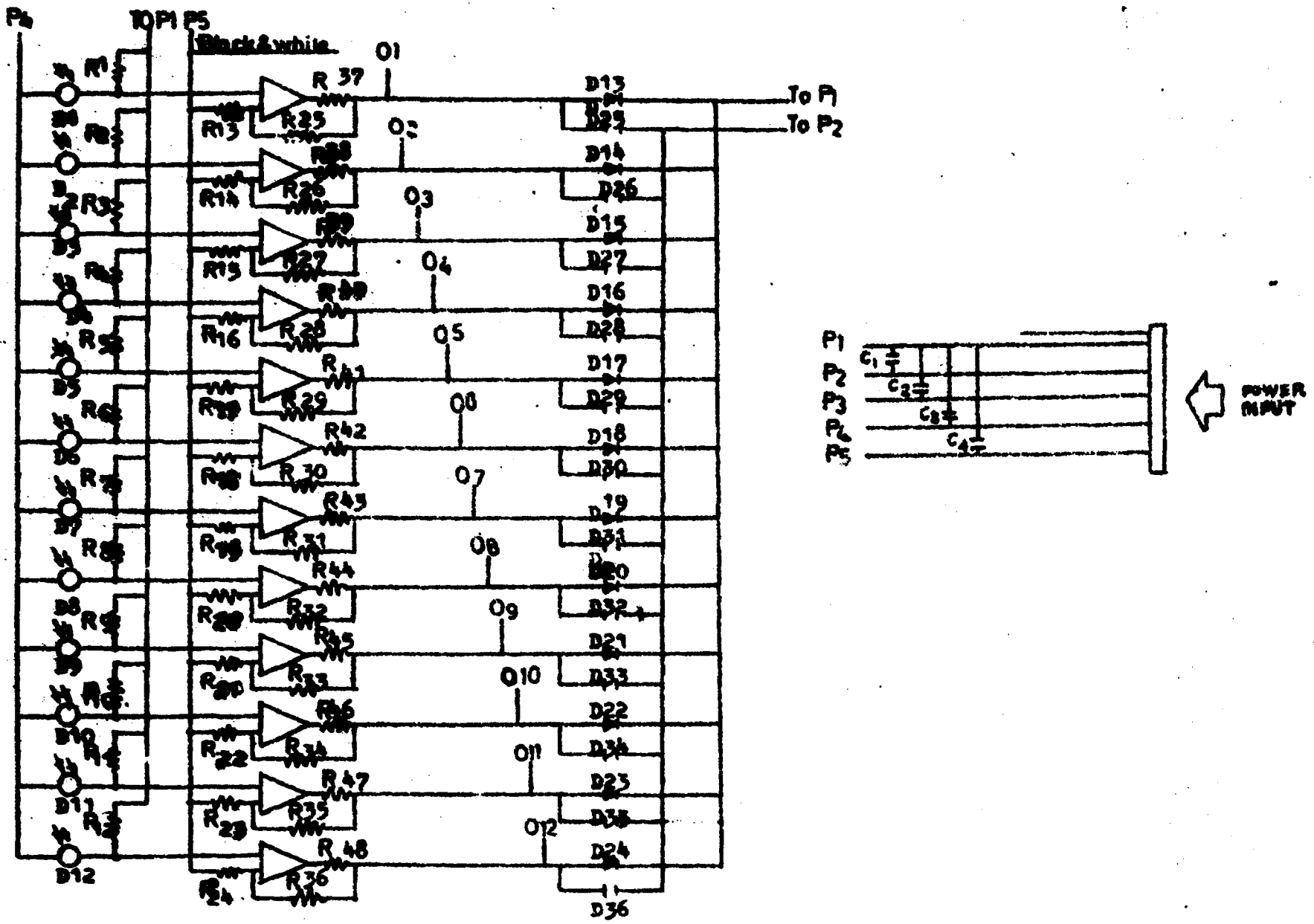


FIG 8 Schematic diagram of digitizer Disc-I

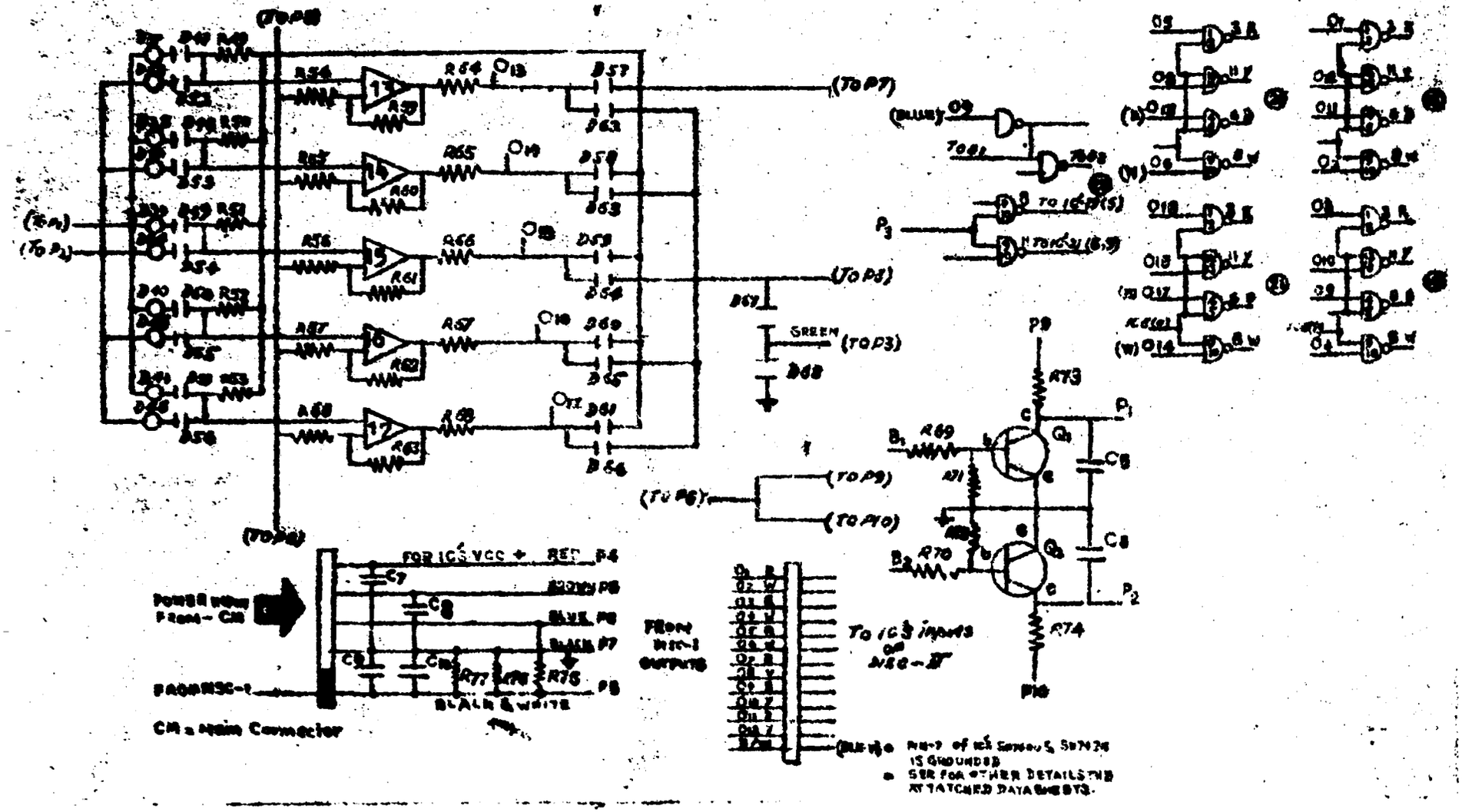
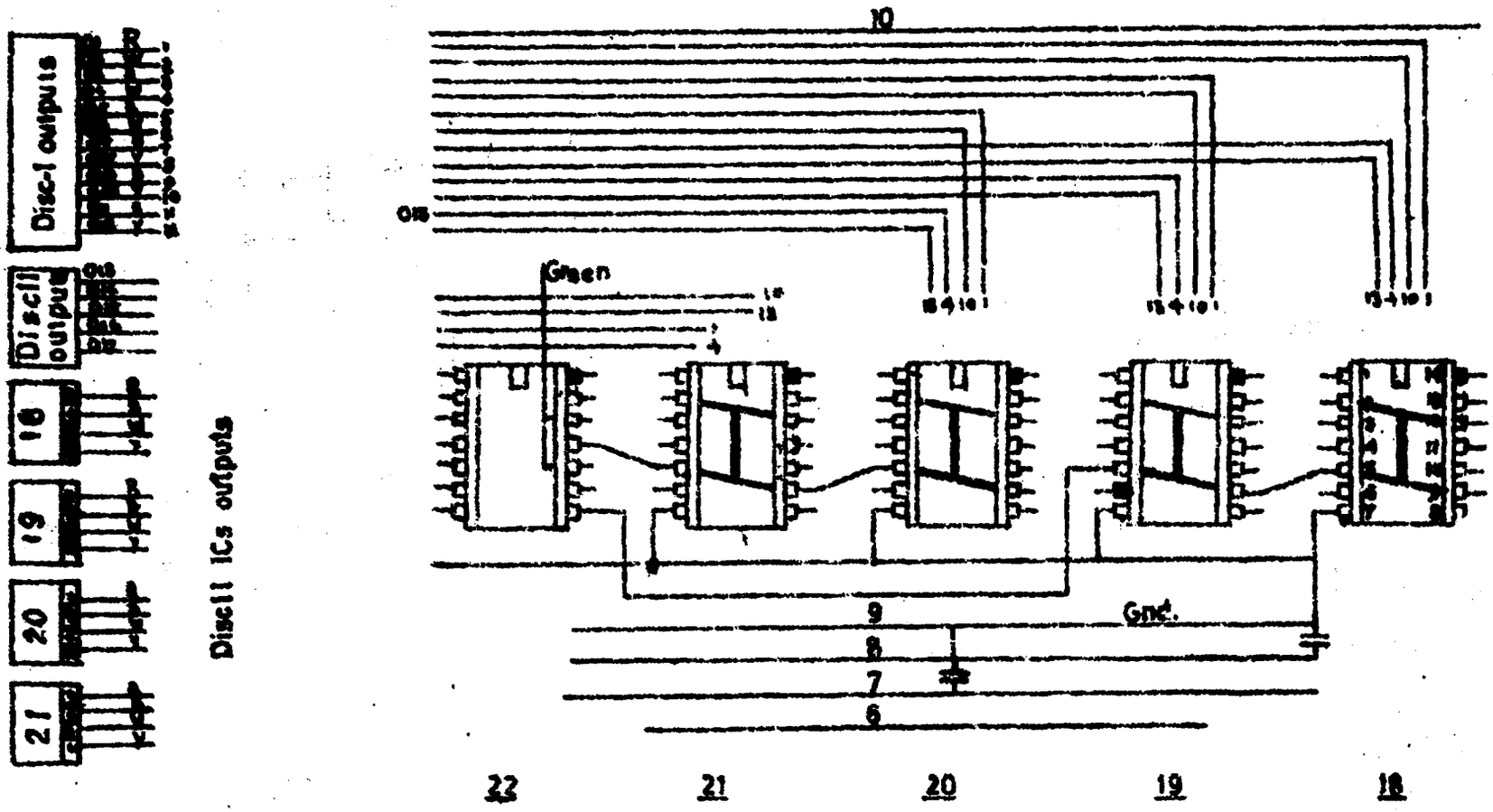


FIG.9. SCHEMATIC ELECTRONIC DIAGRAM OF DIGITIZER DISC-II



18-----22 are output ICs.
See figure captions-10

FIG—10 Input & output wiring diagram of output ICs Disc-II

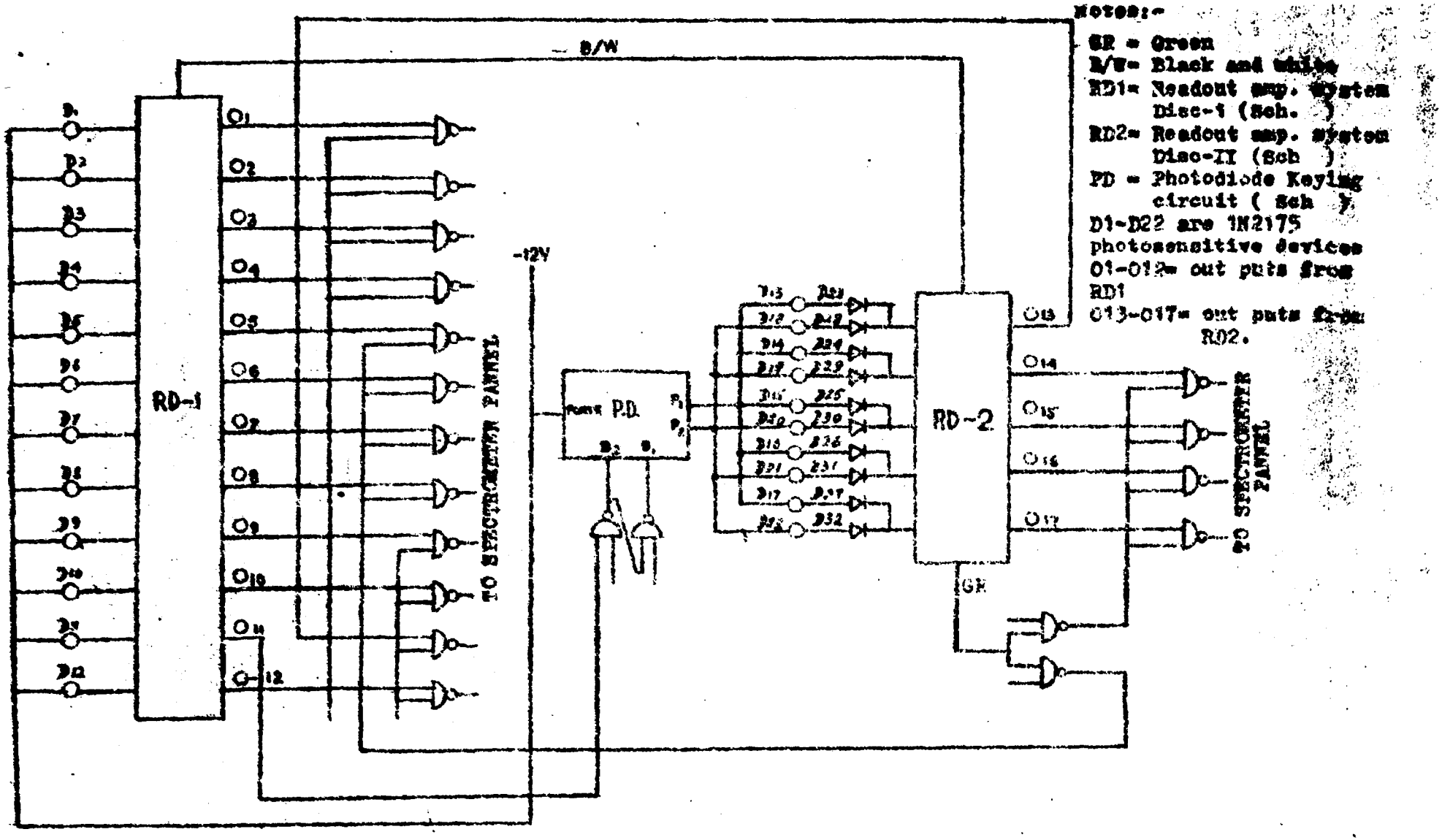


FIG-11. Schematic electronic diagram of digitizer PAC-4.

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