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GENERAL PURPOSE PRINTED CIRCUIT BOARDS FOR DIGITAL AND ANALOG ELECTRONIC CIRCUITS

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1. Introduction

Several years ago circuit design and implementation changed from discrete components to integrated analog and digital circuits. The increased functional complexity of these new IC's resulted in higher circuit density per board or card and higher power supply and circuit interconnection requirements. Frequently special purpose printed circuit boards do not satisfy these requirements economically, especially where a good deal of flexibility for changes is desirable or in the case of the "one of a kind" circuit.

Additionally, Data Analysis' Hummingbird Systems, HB2 and HB3 (CRT flying spot digitizers for automatic film measuring) required the use of fast digital circuits close by and mixed with low noise, high stability analog circuits. For this purpose a high quality power distribution was needed for card files and circuit cards. Ground and power planes with distributed capacitive decoupling and low inductivity were selected to provide good RFI shielding and noise immunity properties.

In an effort to find solutions to these problems a set of general purpose Printed Circuit (PC) boards was developed and successfully utilized for various hardware projects during the past two years.

2. General Description

The PC boards to be described here are used in a "mother-daughter board" configuration. (Key physical dimensions for all boards are given in Table 1). The mother board is a printed file backplane accommodating ten circuit cards and one power input card with card edge connectors. The backplane is a structural member of the card file providing location and support for edge connectors, as well as 6 independent ground or voltage distribution planes and printed circuit patterns for local voltage regulators for each card. It also acts as a heat sink for power-dissipating components and as a shielding plane between cards and file backplane wiring implemented with wire-wrapped connections.

All circuit cards are based on the standard 4.50" x 6.50" size and have printed power distributions in form of busses or ground and voltage planes. Printed mounting patterns for dual-in-line sockets allow assembly with up to 98 each 16 pin sockets per board (double card) or a smaller number of sockets of mixed sizes. High-frequency capacitor power decoupling is locally provided for each 16 pin socket along with separate voltage and ground pins for wire-wrapped socket power connections. In addition each card has low-frequency power decoupling with electrolytic capacitors. Some special printed patterns are suited to mount trim potentiometers, test points and similar devices. Each regular size card has 44 I/O fingers with 4 fingers permanently assigned to voltage and ground inputs. All signal wiring on cards is done in wire-wrap.

Two cards are available with 6 continuous ground and voltage planes for card file power input and in-between card shielding applications. Each plane is connected to 6 card fingers. When used as a file power input card these 6 groups of 6 card contacts each establish a direct connection to the 6 planes of the file back plane. Voltages and grounds are supplied to the file power input card by cable or special laminated chassis bus.

Finally for development and maintenance work an extender card assembly was developed which features signal conductors surrounded by reference ground conductors on four sides. The card has also a patch field that allows special interconnections of different traces and a selection of the reference ground connection by a wire jumper.

Sections 3 through 7 present a more detailed description of these PC boards. A cost analysis for this hardware at various levels of final assembly is given in Section 8, and Tables 2 and 3.

3. Card File Backplane

The backplane is fabricated from 1/8" thick glass-epoxy board and used as a structural part of an assembled card file. It provides mechanical and electrical mounting and connection for all card edge connectors. Figure 1 shows a partially assembled backplane with several typical card voltage regulator circuits. Figure 2 gives artwork details for both sides of the board.

Each side is primarily occupied by one major and two minor conductor planes. The two major planes, #1 and #4, are used as digital ground and supply voltage planes respectively. A typical assignment for the four minor planes is as follows: $\pm$ 15 volt supplies for analog circuitry on planes #5 and #6, analog ground on plane #2 and an auxiliary ground (or supply voltage) on plane #3. This results in well protected supply voltage planes on the card connector side of the backplane and ground planes on the wiring side of the file. Four wire-wrap pins are provided next to each card location for wire connections to the appropriate card contacts.

The major planes for the digital supply circuit have etched patterns for a local point-of-load voltage regulator for each card slot (note exception for card J110 to be described later). The circuit diagram for a regulator is shown in Figure 3 with some circuit and performance parameters tabulated. Proper selection of input resistor R1 provides current limiting at the output and also short circuit protection for the Helipot regulator unit.

The output provides more than 2A of current at nominally +5V Vcc to the card connector. Maximum voltage drop between regulator output and circuit card due to connector contacts is 6mV. Power supply voltage required for plane #4 is typically between +9V and +11V for satisfactory regulator operation.

For applications where no regulators are desired a simple RC decoupling circuit as shown in Figure 1 for card location J105 will provide some isolation between cards. Card location J110 has no regulator circuit of its own. Instead it is supplied from the J109 regulator. Additional pads are available to install an RC decoupled connection.

Digital ground and Vcc voltage conections are permanently assigned to card contacts 20,x and 21,y respectively. Hence after installation of edge connectors and regulator circuits the digital power supply distribution is completed. Edge connector J0 is used as power and ground input to the six conductor planes of the board. All pins are utilized and soldered to the power planes.

4. 28 DIP Socket PC Cards

The given description applies to both 28 DIP cards, since the general layout is identical. Differences in detail are pointed out where appropriate.

The photograph in Figure 4 shows both types of cards as bare PC boards and assembled units to demonstrate some of the provisions of these cards. The artwork layouts in Figures 5 and 6 provide patterns for 28 sockets with 14 or 16 pins with standard 0.100"x 0.300" pin spacing. Between columns of sockets a pattern of busses is arranged on both sides of the card for digital ground and voltage distribution from card fingers (20,x) and (21,y). Between rows of sockets, pads and plated-through holes are located to install a HF decoupling capacitor with ground and Vcc power distribution wire-wrap pins for each available socket. Only very short wire-wrap links are needed to connect socket pins 8 and 16 to the decoupled Vcc post and the appropriate ground post for a particular DIP socket. For low-frequency power decoupling a capacitor is installed next to card fingers (20,x) and (21,y). All other fingers are terminated on wire-wrap posts for custom signal wiring.

The ground bus trace extends up to the top of the card with additional pins and grounding provision for a card handle or a special component bracket. The top portion of the cards is used for special patterns to accommodate non-DIP circuitry or connections to components mounted on special card brackets.

Card type A (GP-910-10-46) has mounting pads for 2 groups of 3 trim potentiometers on each side of the card. In the middle is a termination pad field for a 26 contact connector (MS26RM) for a cable I/O connection. This pad field is also suitable for mounting of special discrete components.

Card type B (GP-910-10-48) has mounting pads for a total of 4 trim potentiometers. Four circular patterns can be used with or without sockets for metal can packaged transistors or integrated circuits. Several additional pads may be used to terminate coaxial connectors on a card bracket or to bring out circuit test points.

5. 44 and 98 DIP Socket PC Cards

The basic card pattern employed, packages 44 sockets of 16 pin size on a standard 4.50" x 6.50" circuit card as shown in Figure 7. Separate voltage and ground distribution pins are installed for each socket. HF decoupling capacitors are shared by 2 sockets. An electrolytic decoupling capacitor is located right at the power input fingers of the card (20,x, 21,y). Digital supply voltage and ground are distributed with continuous planes on both sides of the card as seen from the artwork in Figure 8. These planes continue throughout all socket locations in form of a fine-structured mesh. A much coarser grid of solid conductor sections in each plane forms corridors for dc current distribution. From the largest dimension (~ 6mm) of a typical hole in the fine mesh, i.e. the clearance area for one of the double pads, it is seen that these mesh sections perform as effective ground planes for frequencies in excess of 10^9 Hertz.

To satisfy particular circuit requirements the printed socket mounting patterns accept all socket sizes with 0.300" row spacing up to 16 pins and all socket sizes with 0.600" row spacing up to 40 pins (not accepted is the 18 pin socket). These sockets of different sizes can be mounted and mixed in a variety of configurations as demonstrated in Figure 7.

Based on the regular size 44 DIP socket card (GP-910-10-42), a double card was desigend. This double card (GP-910-10-51) accepts 98 DIP sockets of 16 pin size. A card example is shown in Figure 7 demonstrating the mixing of different sockets described earlier. The artwork for both sides of this card is shown in Figures 9 and 10. The 98 DIP card has 80 card contacts available for signal I/O. 2 times 4 contacts are used to supply the two card power planes. The overall card size is 6.50" x 10.25" with a card finger pattern spacing for corresponding contacts of 5.75" (146 mm). The large center isle provides mounting pads for large electrolytic capacitors for LF power decoupling or some special circuit requirements (long period timing circuits, etc.).

For applications not involving the use of card files this double card may be employed as a logic board. Three such boards can be housed in a drawer chassis with 1 3/4" x 19" front panel, accommodating almost 300 IC packages. This is equivalent to a full card file with 10 each 28 DIP cards.

Along the top of 44 and 98 DIP cards, provision is made to mount trim potentiometers as shown in Figure 7. Separate pad holes are used for each potentiometer pin and its associated wire-wrap pin. The maximum number of potentiometer locations is seen to be 12 and 28 for single and double size cards respectively.

A set of 4 mounting holes is also found at the top of the 44 DIP card. The top pair of holes is for attaching a standard card handle or a component bracket. The pair of holes right below (spaced slightly farther apart) is centered along the top row of 4 sockets. These holes may be used to attach a retaining bar for flat I/O cables with DIP plugs connecting to sockets All to D11. A similar set of holes is found along the top end of the 98 DIP card for the same purpose.

6. Card File Power Input and Shielding Cards

The File Power Input Card GP-910-10-67 was designed for use with backplane card slot J0. The artwork in Figure 11 shows the card has 3 conductor planes on each side with six card fingers for each plane. Six card fingers allow a maximum of 30 Amps at 30 mV voltage drop per conductor plane based on card edge connector contact rating. All planes terminate at the top end of the card with plated-through holes allowing bolted connections of wires from power supplies. Furthermore, all 3 planes of one card side are connected to the other side by these plated holes. Here six contact areas of approximately 1 in.^{2} (6.5 cm^2) each are arranged for making a HF quality connection to the 6 power planes. The development of a sliding large area power contact arrangement is suggested, providing a high quality power connection from a flat, laminated chassis or rack bus to the power input card of a file backplane. For improved DC current capability, screws with appropriate washers can be used for the 3 planes connected through from the opposite side.

Along the top edge of the card, pads for LED voltage indicating circuits are available with trace connections to all 6 planes. An additional trace connects card handle mounting holes to plane #1 assigned to digital ground on the backplane.

The Shielding Card (Voltage Plane Board, GP-910-10-09) is an earlier, simpler design. The artowrk is given in Figure 12. The six conductor planes may be accessed again with bolted wire connections at the top of the card. However another use of this card is as a ground plane for shielding between 2 cards in a file. The card, assembled with a mylar and a Mu-metal sheet on both sides and all conductor planes grounded, has been used as an effective EMI/RFI shield in card files. The hole located 1.5" from the top edge is used to connect the two Mu-metal sheets of the sandwich to each other and by a jumper wire to one of the printed card planes.

7. Extender Card Assembly

The last PC board to be described here is an extender card assembly with improved signal trace isolation and shielding. Sample units of this card are pictured in Figure 13. One card is shown with only the edge connector attached to exhibit the basic trace arrangement and details of the edge connector mounting. The second card is a completely assembled version. The PC layout is shown in Figure 14.

A comb-shaped reference ground pattern separates signal traces from each other on both card sides. Plated-through holes connect the two patterns. The larger ground trace patches are provided to make contact with the ground planes of the shielding boards after assembly.

A typical cross section with conductor arrangement is given to scale in the sketch of Figure 15. The signal trace is surrounded on three sides by ground traces for isolation. The fourth side is very effectively shielded by the solid ground plane of the cover board. Signal traces and ground plane are spaced typically 0.005" (0.13 mm) apart by a mylar sheet. All ground traces and planes are finally connected by a jumper wire to the appropriate card signal trace for grounding. A patch field of plated holes is arranged next to the card fingers. For special applications, cross connections of conductors or other modifications are easily accomplished there.

8. PC Board Cost Tables and Cost Comparisons

Cost tables were compiled based on charges for cards and labor services during fiscal year 1973. Table 2 lists the cost per PC board with relevant information. Three remarks are in order:

(a) Due to the small number of boards fabricated, the cost of both 28 DIP cards is unusually high. In quantities between 40 and 50 cards, the cost is expected to be relatively comparable to the 44 and 98 DIP cards.

(b) The cost of the extender card reflects the small number of cards fabricated and the significant contribution of parts and labor charges for the assembly with the required edge connector. The cost for a completely assembled card, including shielding boards, is not available and has not been estimated.

(c) The cost for a completely assembled card file backplane is given as a basis for future hardware project estimates. The backplane is finished including high power Vcc regulator circuits in all available places. It is ready for custom system wiring and assembly into a file or chassis.

Table 3 provides a PC card cost comparison using the cost per 16 pin DIP socket calculated for different levels of hardware assembly. The total cost per board is also given for hardware estimates.

9. Summary

A family of general purpose PC boards was described for use with circuits consisting primarily of dual-in-line packaged integrated circuits and similar devices. Some of the special features and capabilities available on these boards were pointed out and explained. A cost analysis shows these boards to be economical with production quantities compatible with the needs of many groups at SLAC. The fabrication of all boards is completely based on well established technologies readily available at SLAC and outside industries.

Further cost reduction is possible with larger production quantities. This might be achieved by supplying interested parties of different groups with these boards through SLAC stores. Complete documentation is available for all items described in this report. Figure 16 is a drawing list for reference.

These PC boards were used with good results for several different hardware projects in Data Analysis. For design layout purposes simplified engineering forms for the different boards were found useful. An example of such a layout form is given in Figure 17.

The "mother-daughter board" concept to partition electronic hardware was chosen, since the inherent modularity offeres many degrees of freedom to accommodate special requirements and modifications. This is judged to be particularly important to many electronic systems designed at SLAC. The high density card, low density card file layout provides for ease of maintenance, modification and further development. Cards and file backplanes as described offer exceptional control of power and ground distribution problems.

10. Acknowledgements

It is a pleasure to point out the significant contributions of ideas and skilled workmanship of D. Bailey, W. Chandler, S. Godfrey, V. Hamilton, R. Nelson and all of the Data Analysis Technical Group. Due to their efforts, I dare say, we are able today to implement electronic hardware better and cheaper by just using some of these PC boards.

Card File Backplane

Board Type: 1/8" glass-epoxy board, NEMA grade FR4, 3 mils of copper both sides (2 oz.) after hole plating.

Board Size: 423 x 132 mm (16.625 x 5.187")

Card Spacing: 40.6 mm (1.60")

Number of Cards: 10 circuit + 1 power input card

Card Edge Connectors: 44 contacts, spacing 3.96 mm (0.156")

Basic PC Cards

Board Type: 1/16" glass-epoxy board as above.

Board Size: 164 x 114 mm (6.50 x 4.50")

Layout Pin Grid: 2.54 mm (0.100")

Socket Pattern: DIP sockets of 6, 8, 14, 16, 24, 28, 36, 40 pins

Row Spacing: 7.62/15.24 mm (0.300"/0.600")

Card Contacts: 44, gold plated, 40 signal +4 power

Double Card (98 DIP)

Card Size: 164 x 260 mm (6.50 x 10.25")

File Center Spacing: 146 mm (5.75")

Card Contacts: 88, gold plated, 80 Signal + 8 power

Extender Card

Card Size: 200 x 114 mm (7.875 x 4.50")

File Extension: 210 mm (8 1/4")

Table 1: Key Physical Parameters for General Purpose PC Boards

BOARD TYPE	COST $	NO. OF BOARDS	DRILLING T = TAPE M=MANUAL	REMARKS
28 DIP Card GP-910-10-46	8.00	20	T	High price is due to small number of cards; card GP-910-10-48 is similar.
44 DIP Card GP-910-10-42	6.50	50	T	
98 DIP Card GP-910-10-51	9.00	35	T	Double Card.
File Power Card GP-910-10-67	5.45	40	M	Shielding Card GP-910-10-09 is similar.
Card Extender GP 910-11-47	22.90	12	M	Card assembled with edge connector.
Card File Backplane GP-910-10-41	14.55	25	T	
Card File Backplane GP-910-10-41 Assembled	372.00 or 37.00 Per Card Slot	Parts and labor cost of assembled backplane including card edge connectors, card Vcc regulator circuits (805-V6+2N3055) and all power distribution wire-wrap pins.		

Table 2: PC BOARD COST

Cost Item Description \ Board Type	28 DIP Card 910-10-46 (48)	44 DIP Card 910-10-42	98 DIP Card 910-10-51
Cost of basic board Per board - $	8.00	6.50	9.00
Per socket location - cents	27.5	14.8	9.2
Cost of board with DIP sockets (16p) Per board - $	31.00	43.00	87.00
Per socket - $	1.14	0.97	0.89
Cost of board assembled with sockets, caps, power pins Per board - $	47.00	67.00	137.00
Per socket - $	1.67	1.52	1.40
Socket Packaging Density in $\left[\frac{\text{Sockets}}{100\ \text{cm}^2}\right]$	15.7	24.7	24.3

Table 3: PC BOARD COST COMPARISON

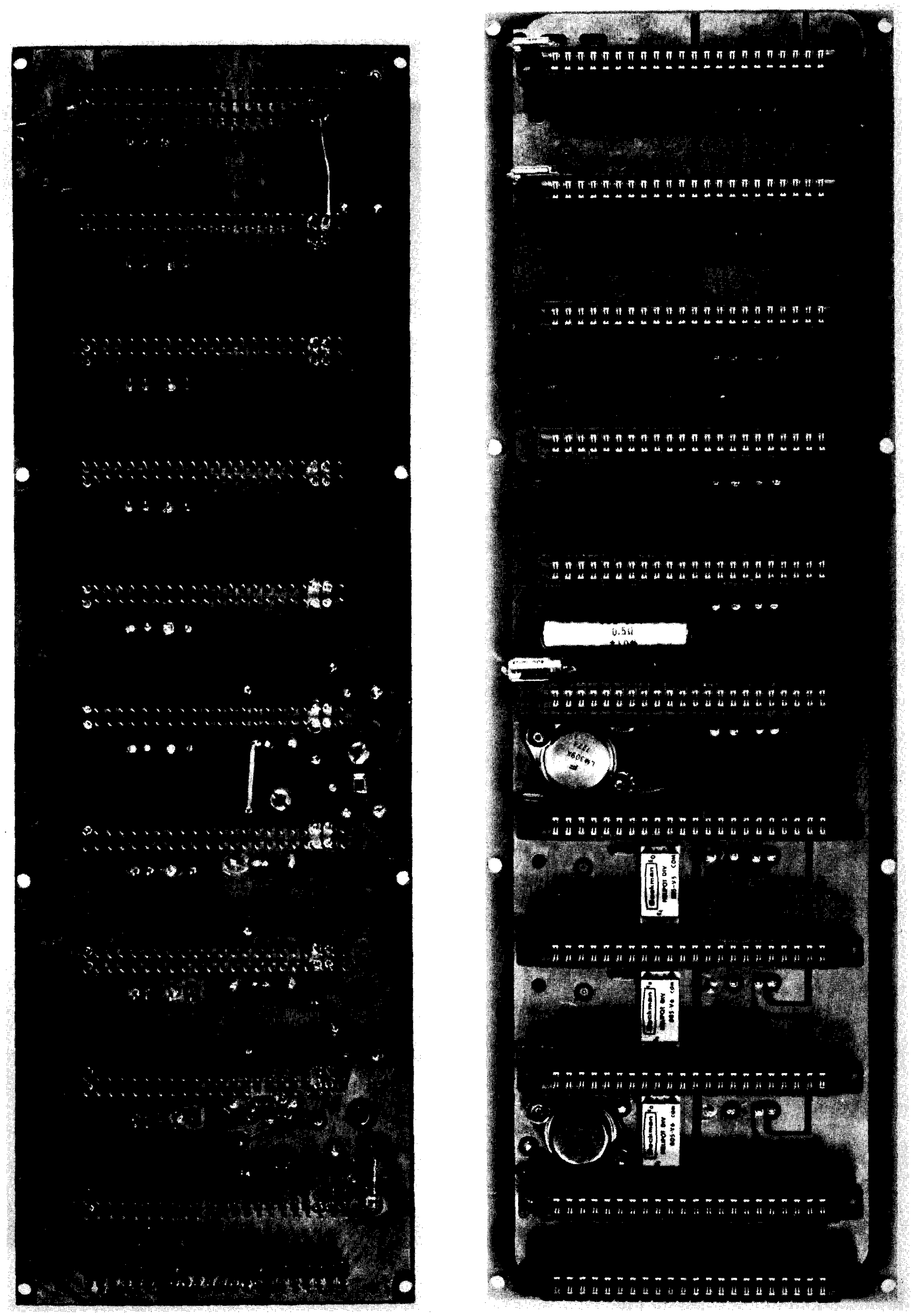

Figure 1: Card File Backplane with Vcc Regulator Circuits

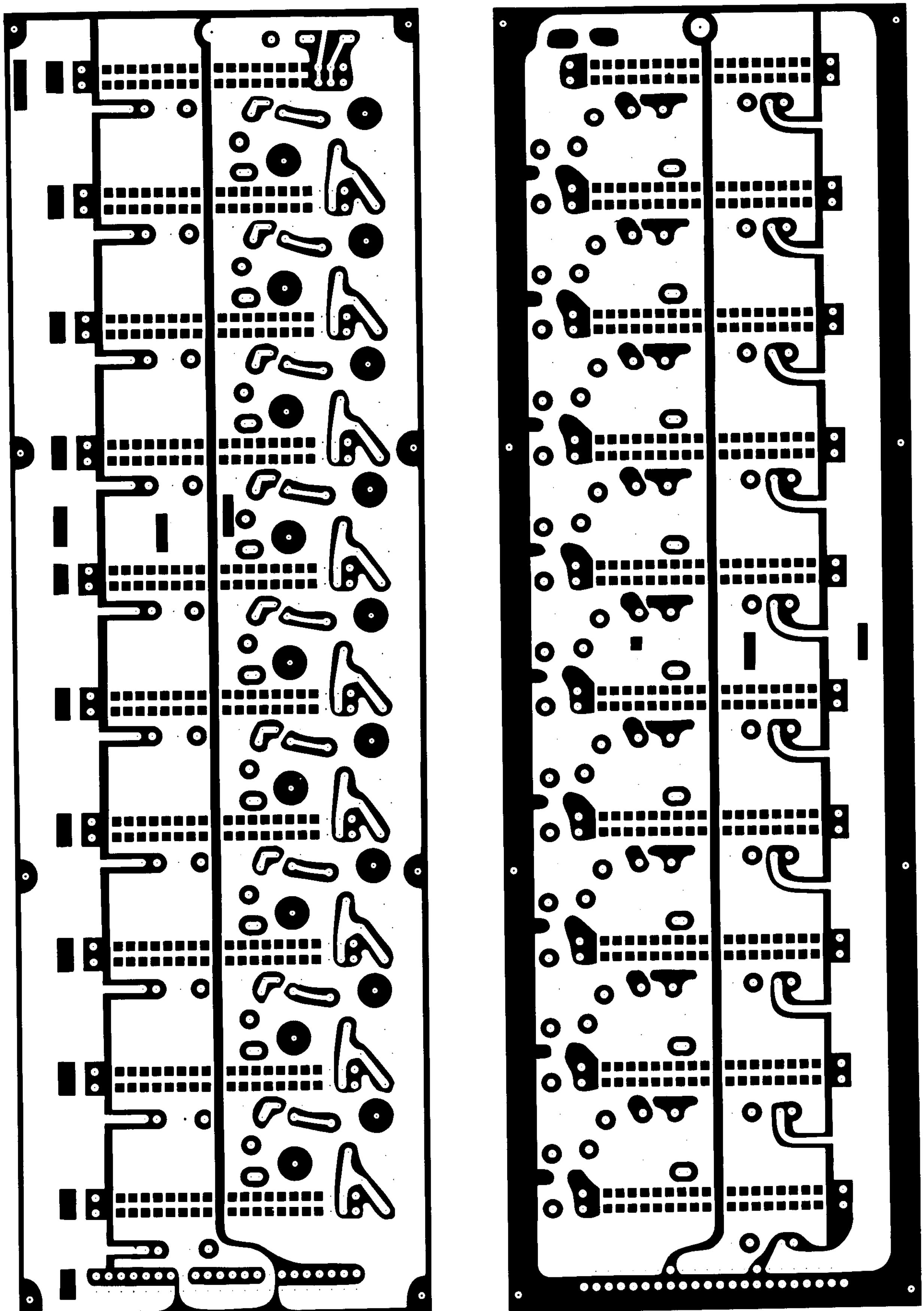

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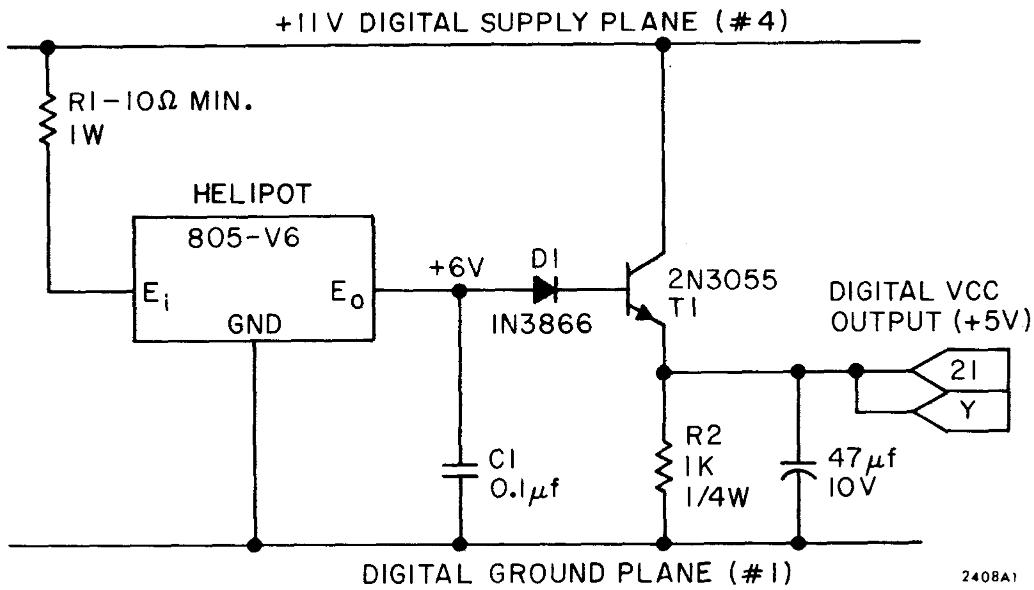
Figure 2: Card File Backplane, Artwork (GP-910-10-41)



Circuit Parameters for 2 Amp Vcc Load

Vcc output voltage	+ 4.6 to + 5.0 Volt
T1 power dissipation	12 Watt
Helipot output current	100 mA
Helipot power dissipation	0.4 Watt
R1 voltage drop	1 Volt
R1 power dissipation	0.1 Watt
Load (no load to full load) and DC input (±10% change) regulation of Helipot	±5mV
Input AC ripple rejection at 100KHz	40 dB
Output impedance at 10 KHz	$\leqq$ 0.1Ω
Output temperature coefficient	± 1 mV/°C

Figure 3: Card File Backplane - Typical Vcc Regulator Circuit

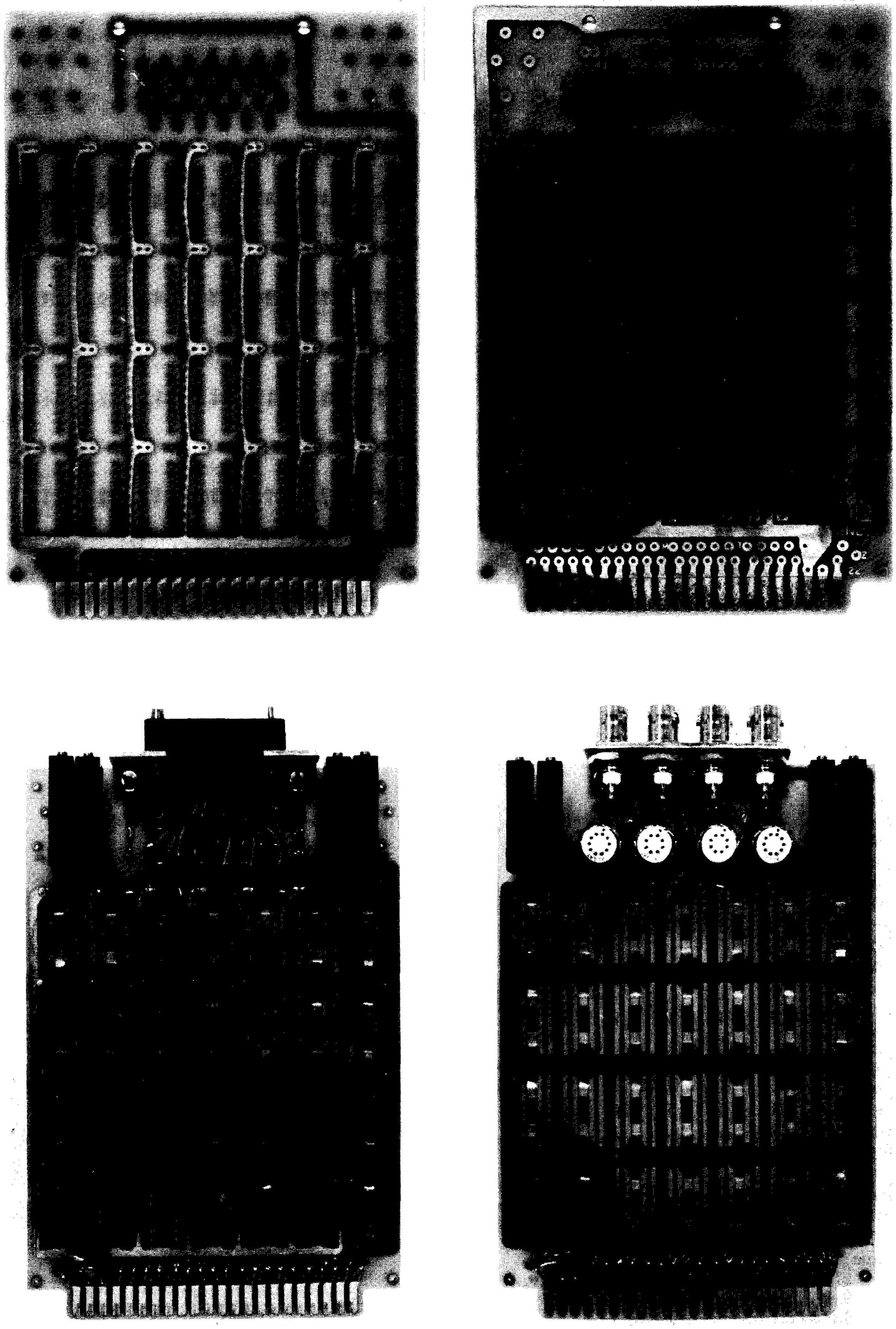
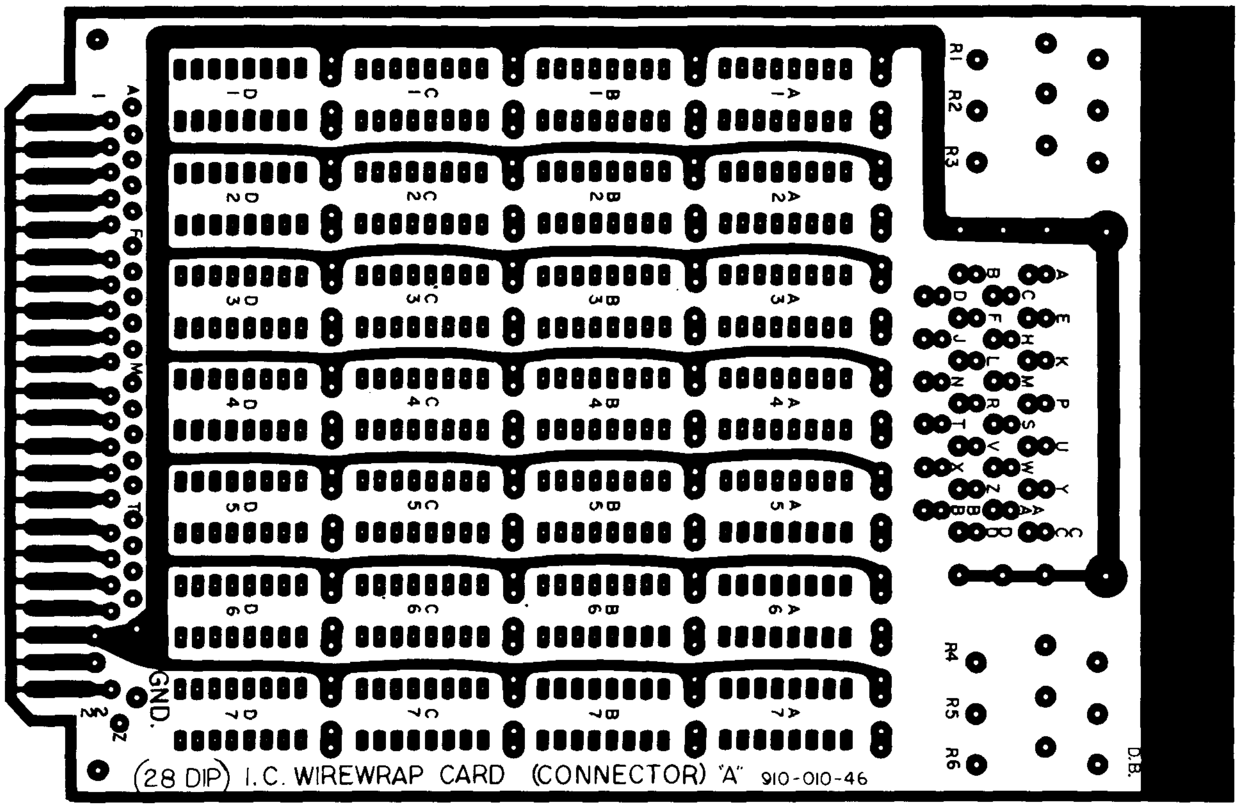


Figure 4: 28 DIP Socket PC Cards (Type A and B)



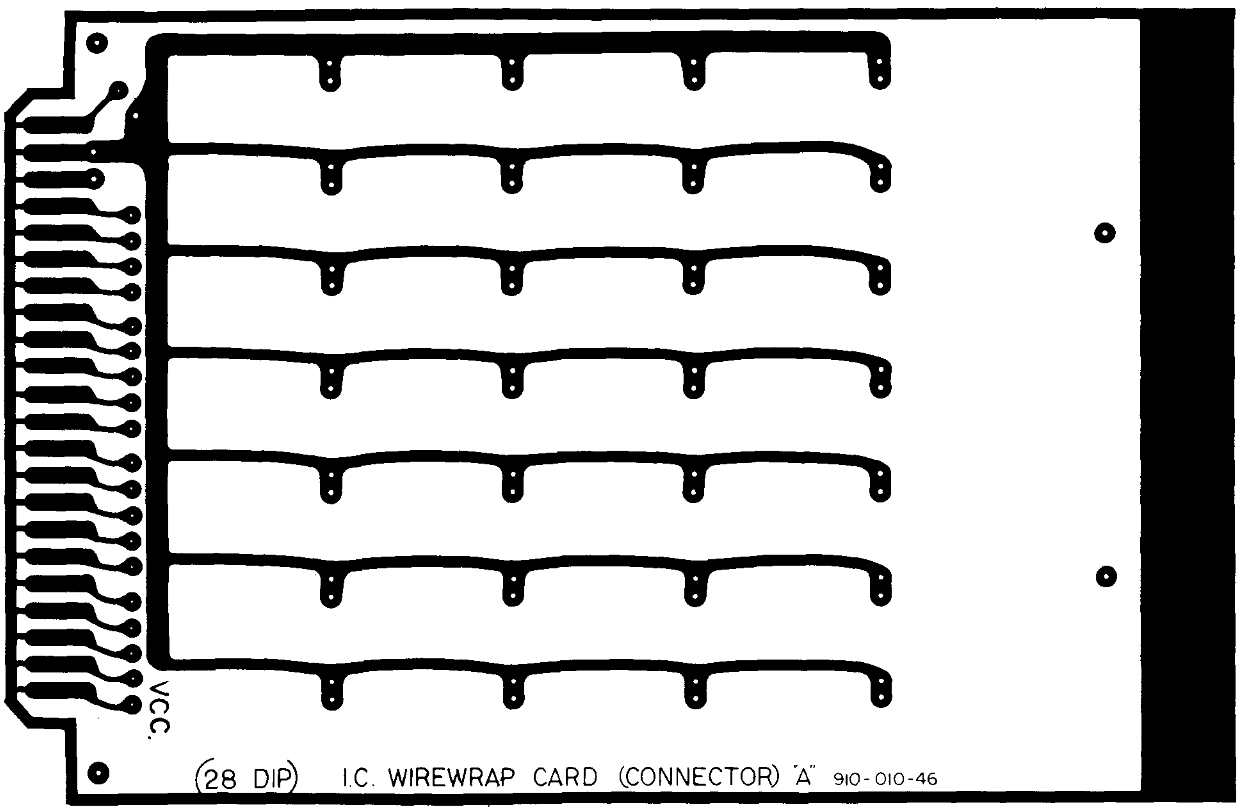


Figure 5: 28 DIP Socket Card (Type A), Artwork

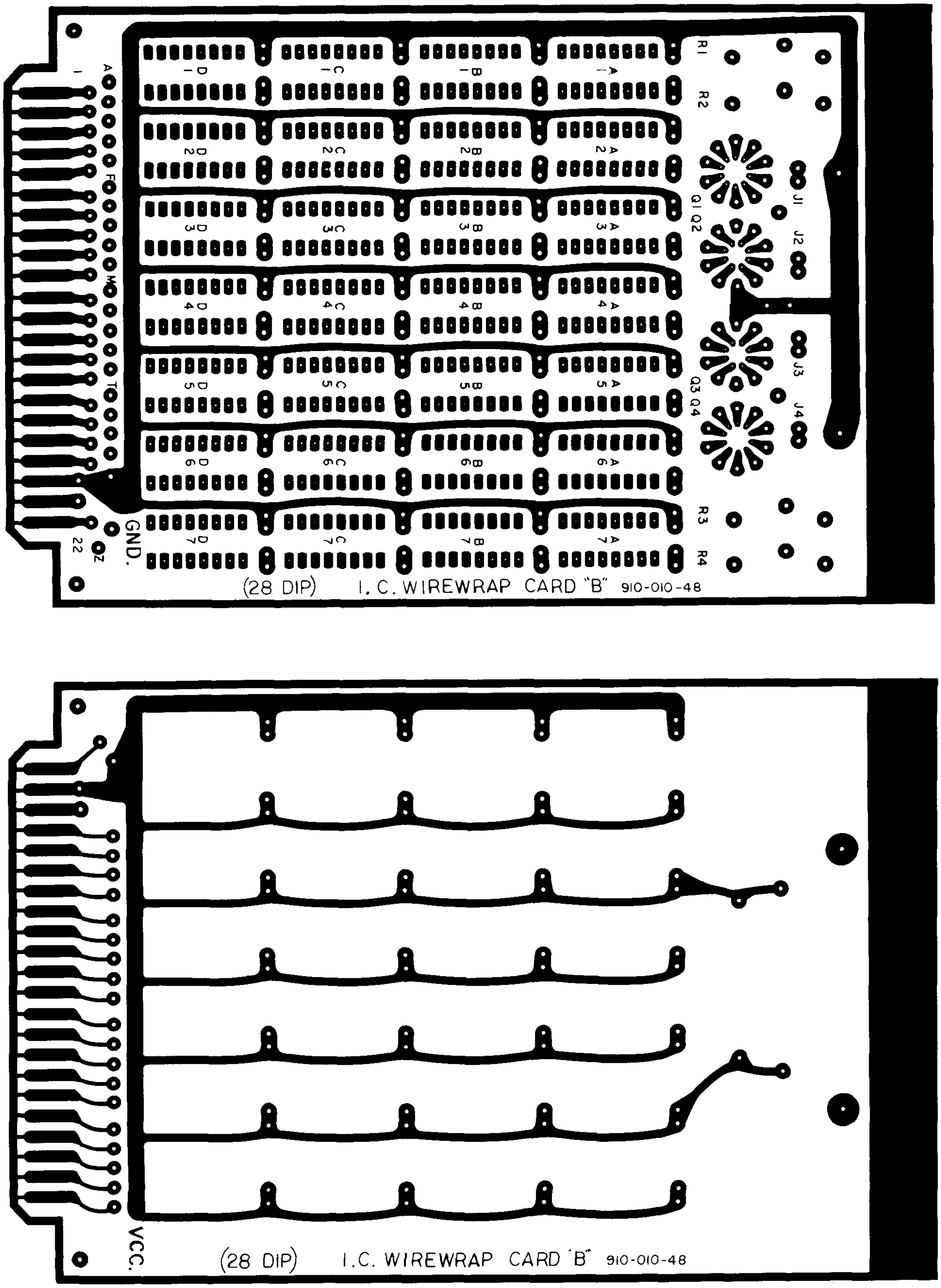


Figure 6: 28 DIP Socket Card (Type B), Artwork

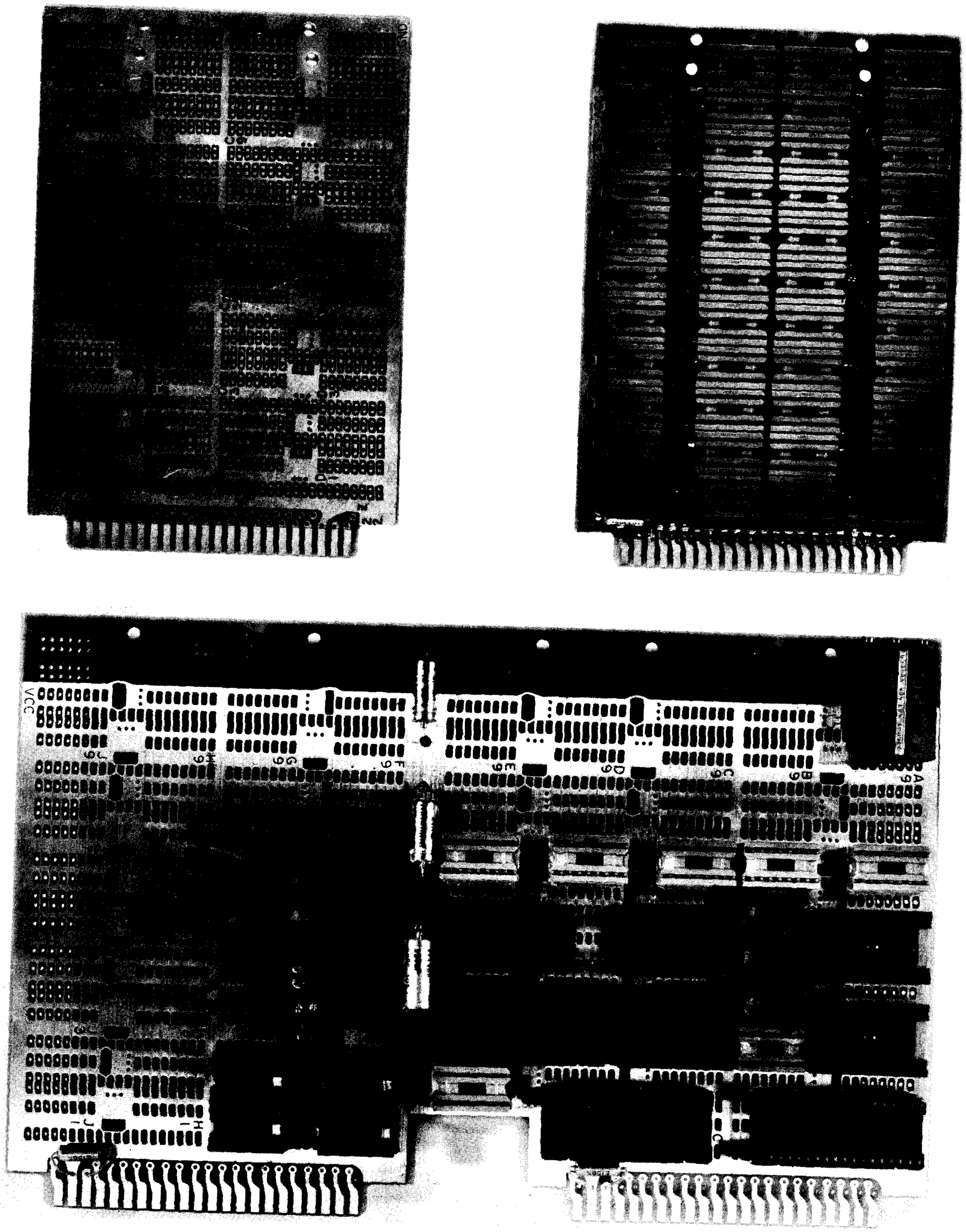
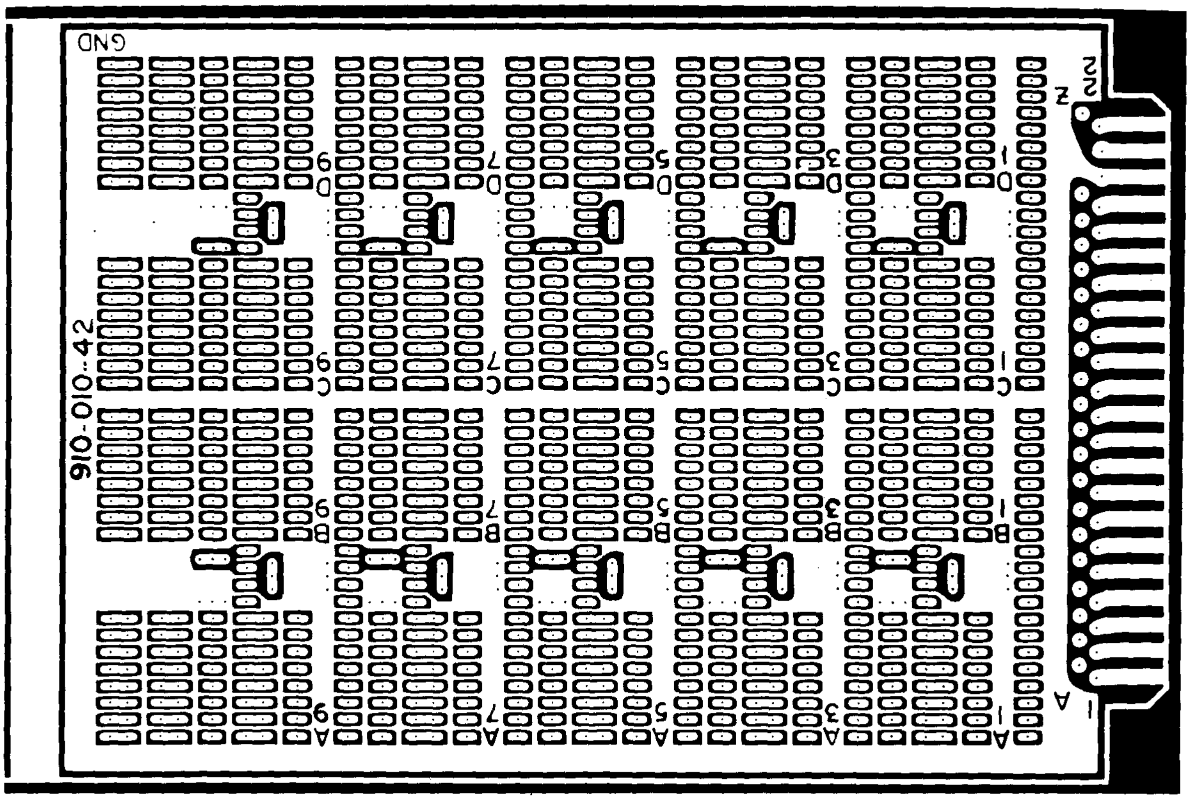


Figure 7: 44 and 98 DIP Socket PC Cards



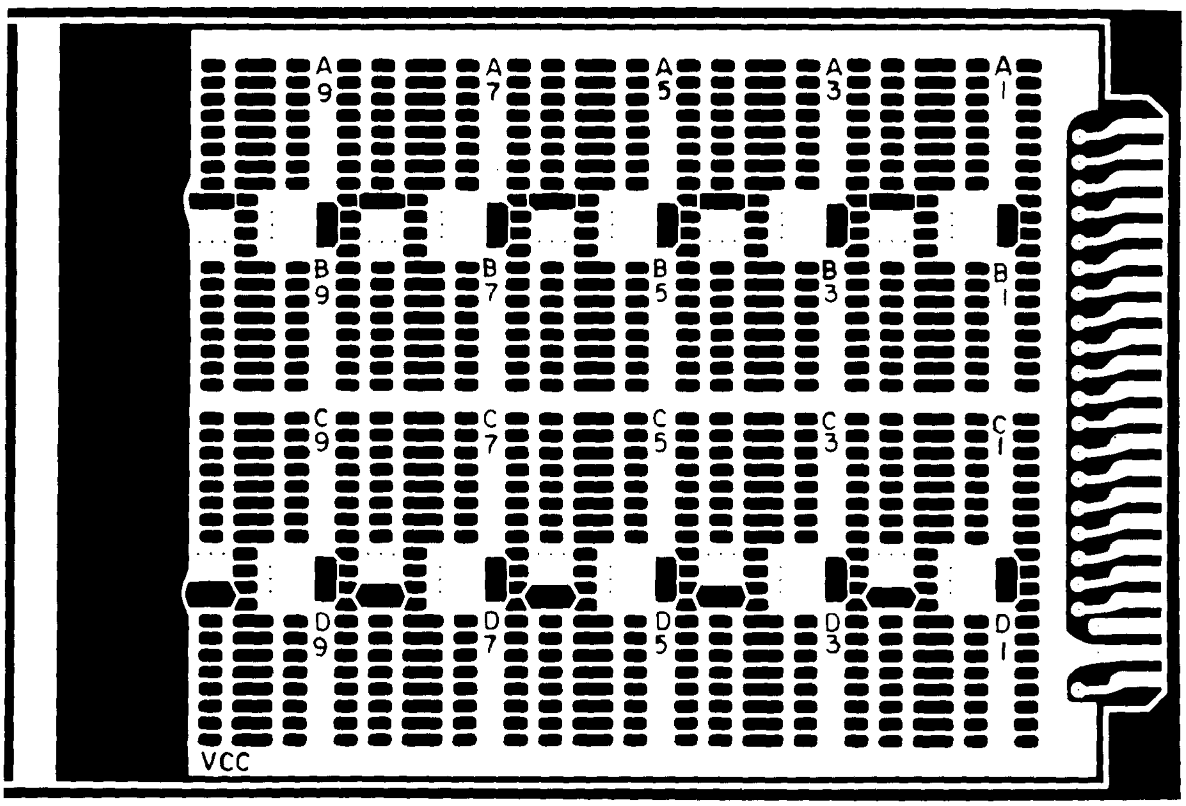


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Figure 8: 44 DIP Socket PC Card, Artwork

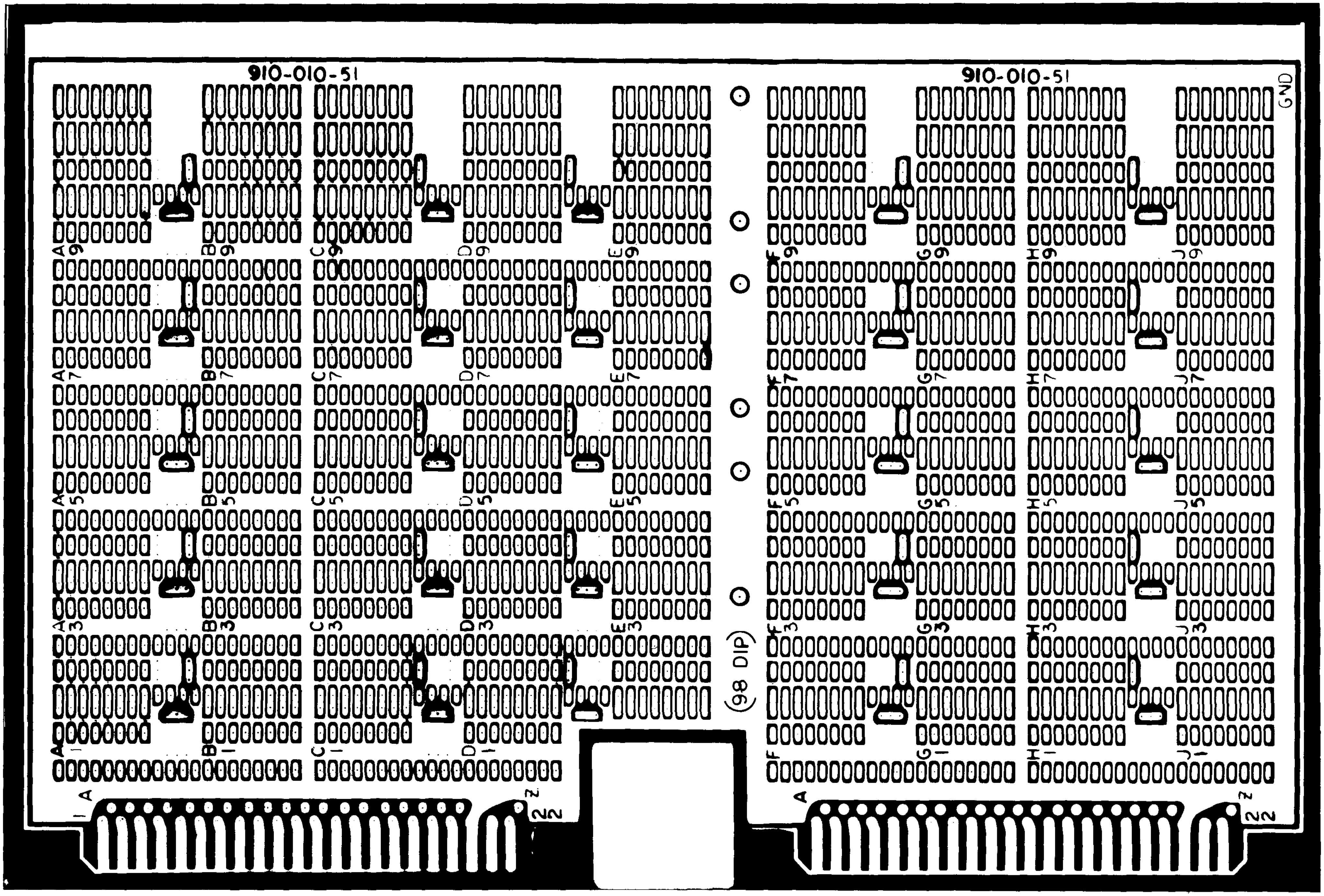


Figure 9: 98 DIP Socket PC Card, Artwork, Wiring Side

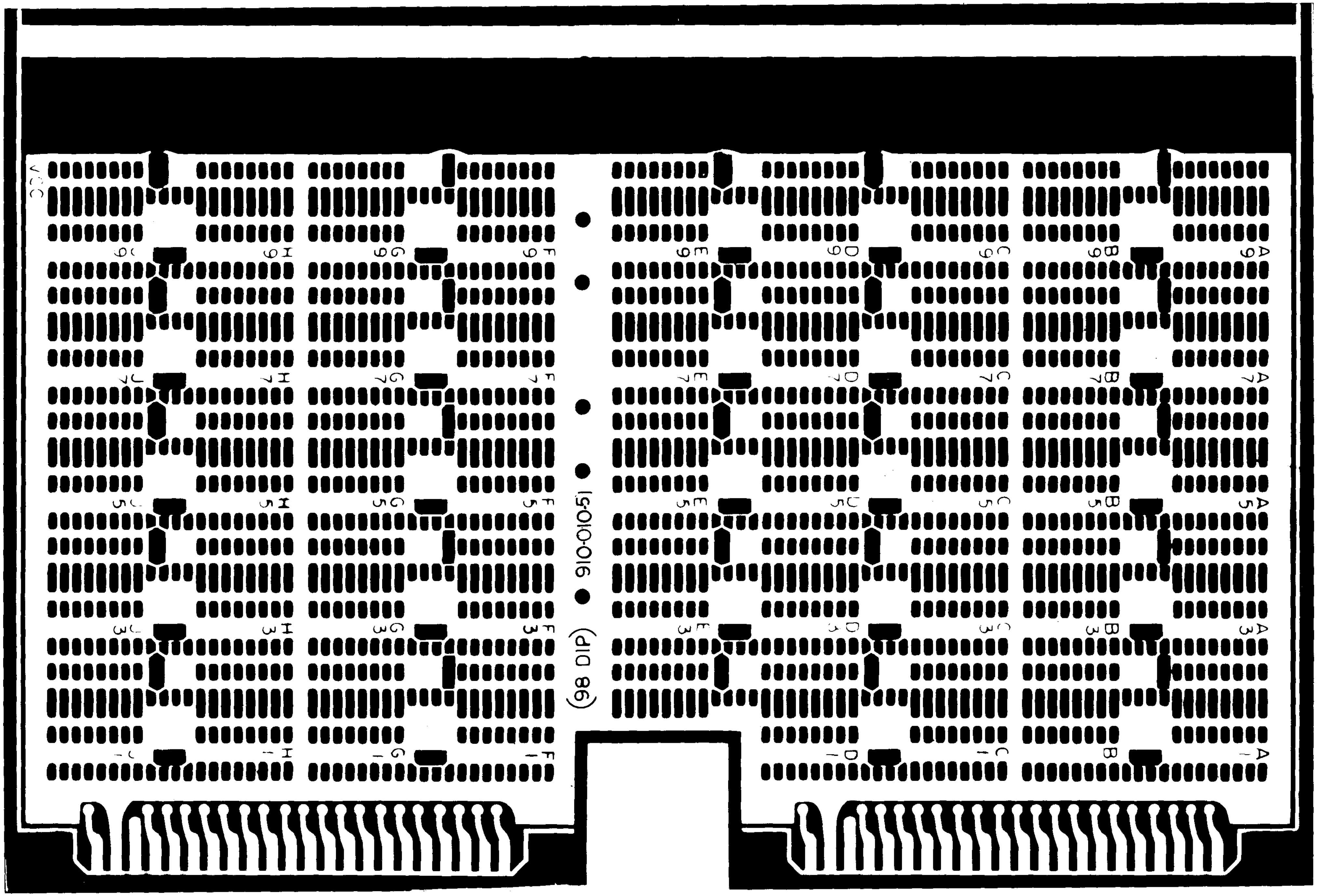
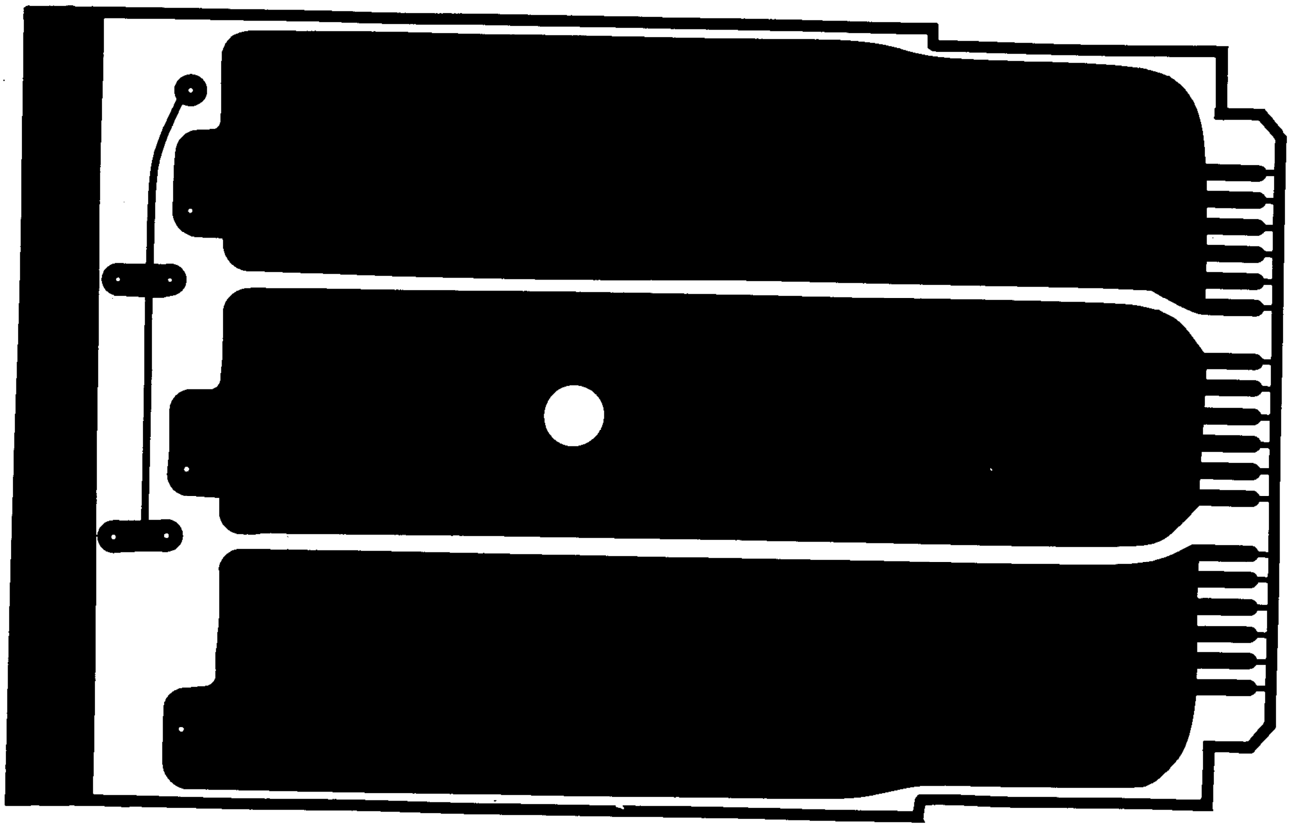


Figure 10: 98 DIP Socket PC Card, Artwork, Component Side



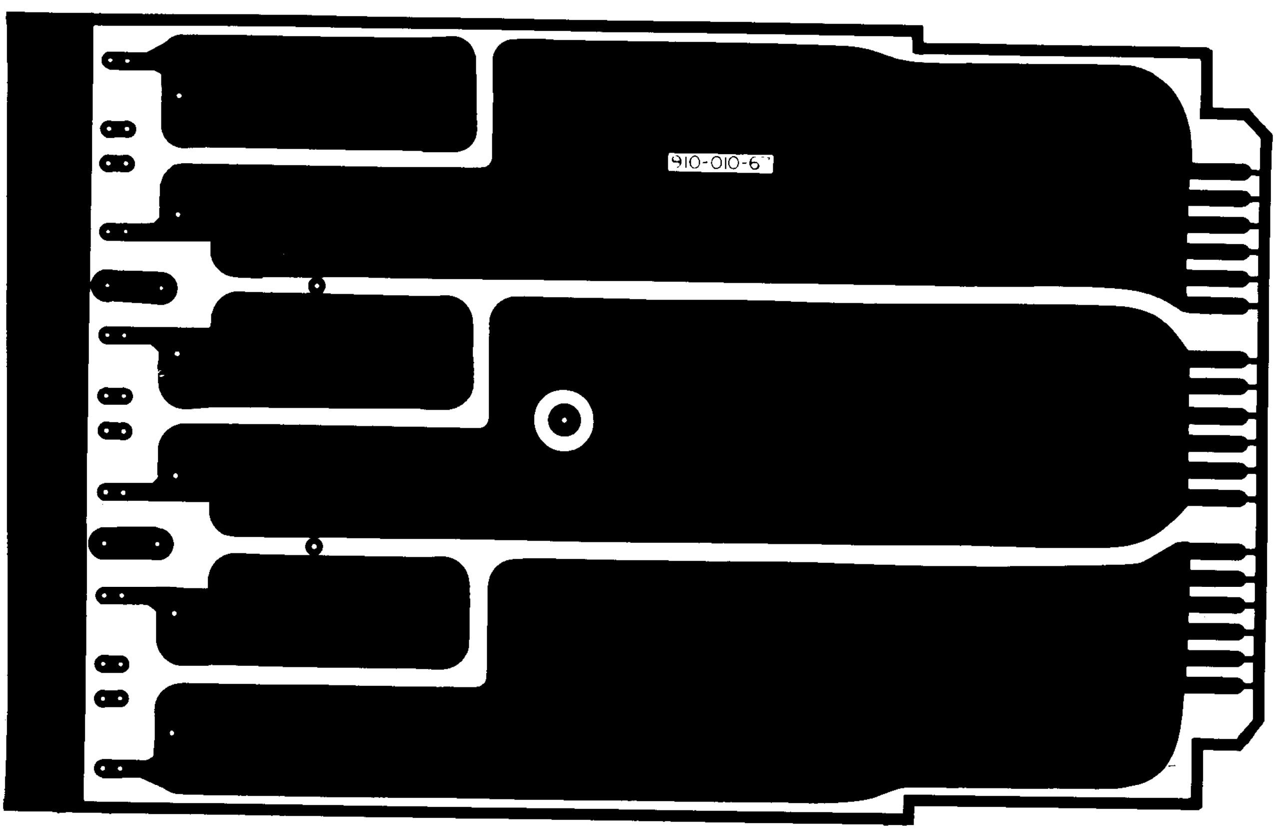


Figure 11: File Power Input Card, Artwork

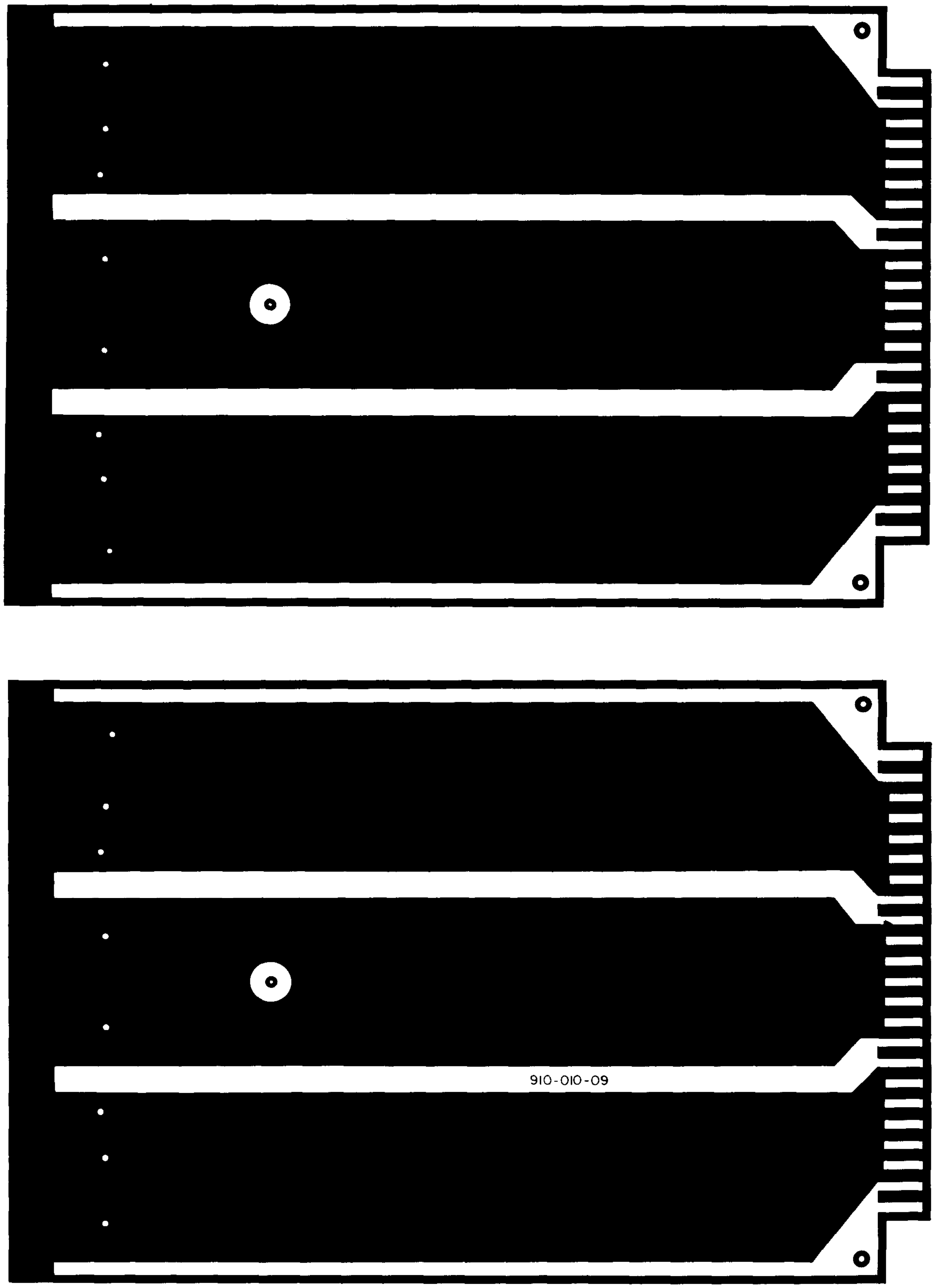


Figure 12: Shielding Card (Voltage Plane Board), Artwork

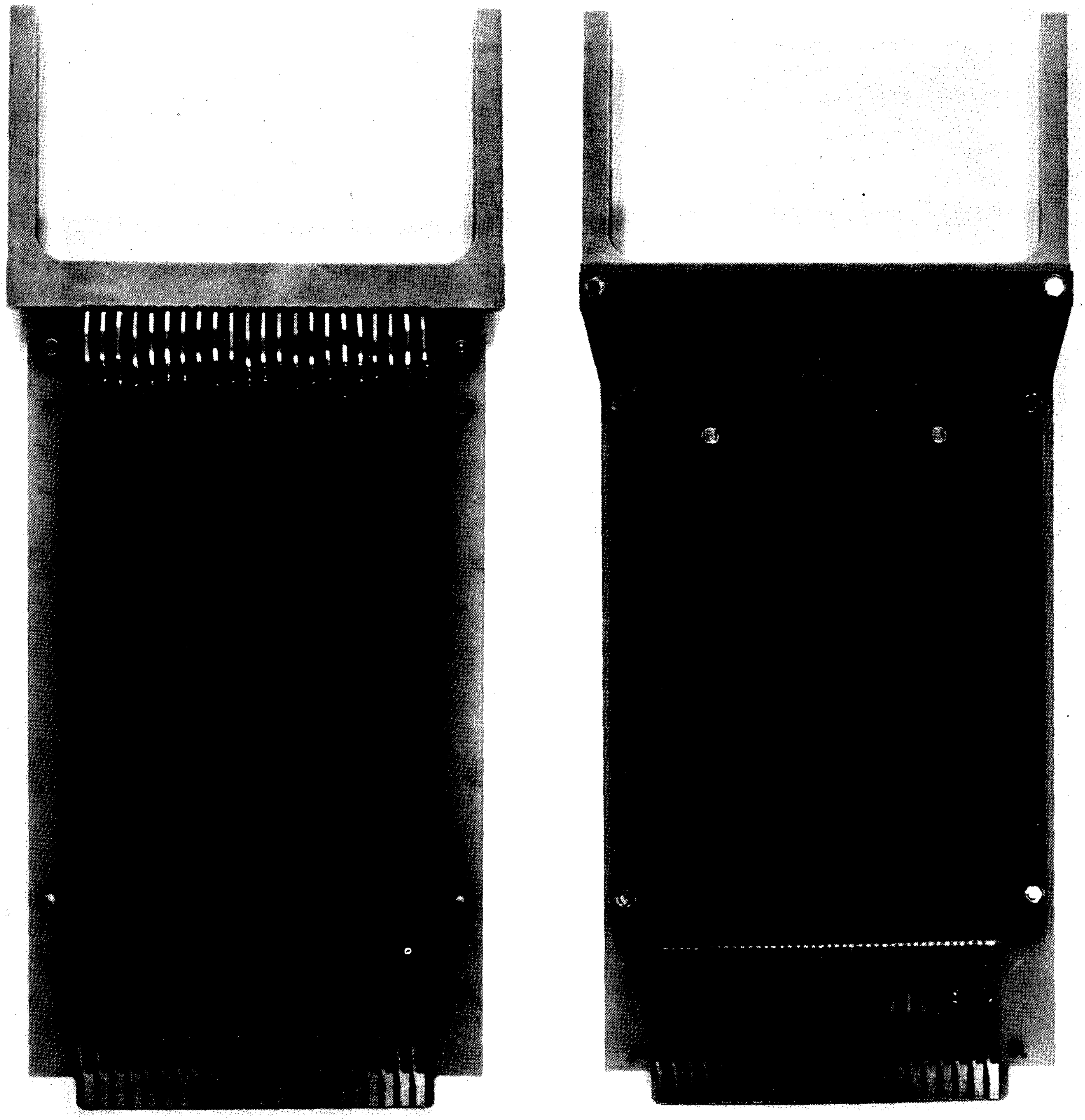


Figure 13: Extender Card (Partially Assembled and Final Units)

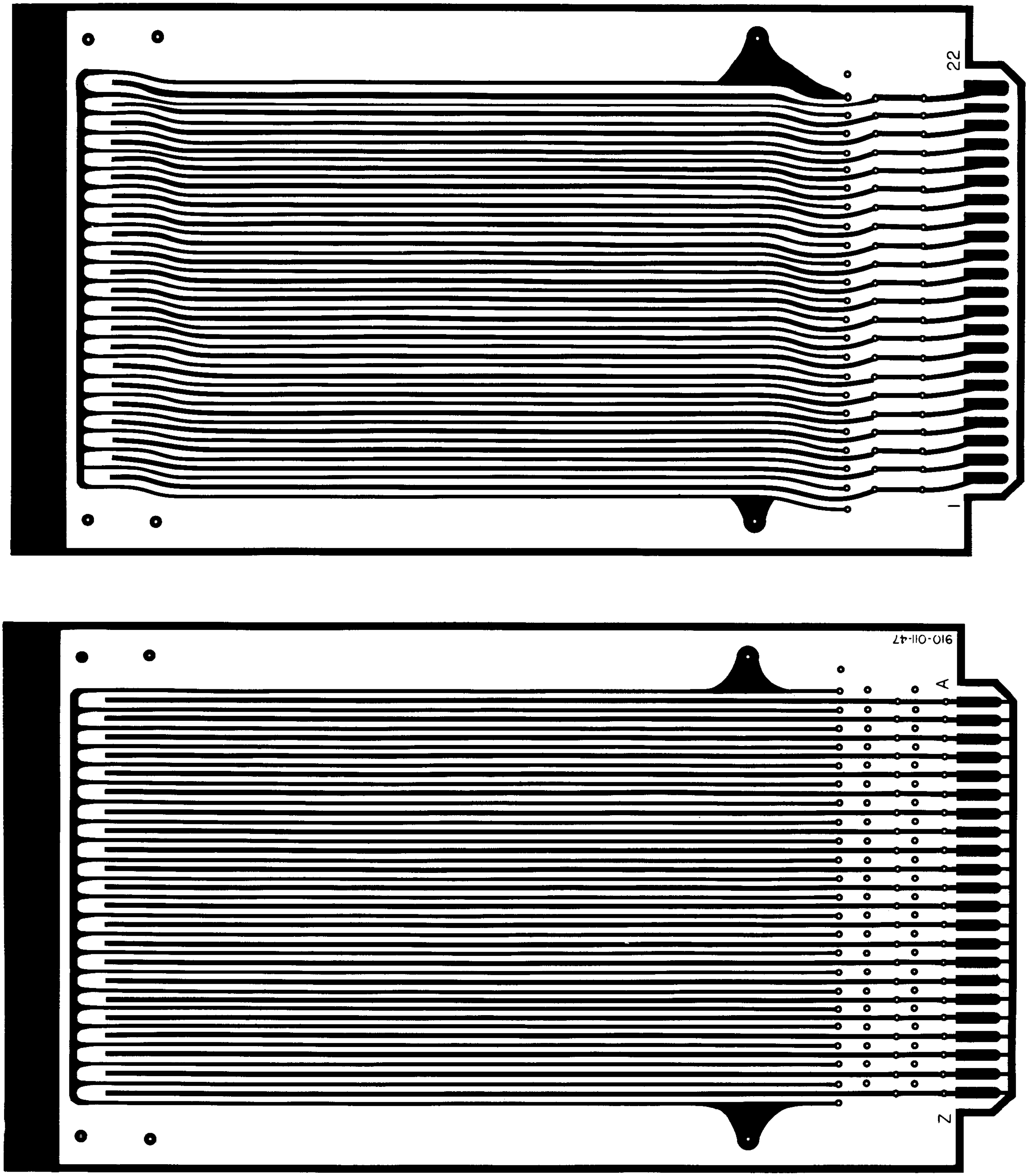
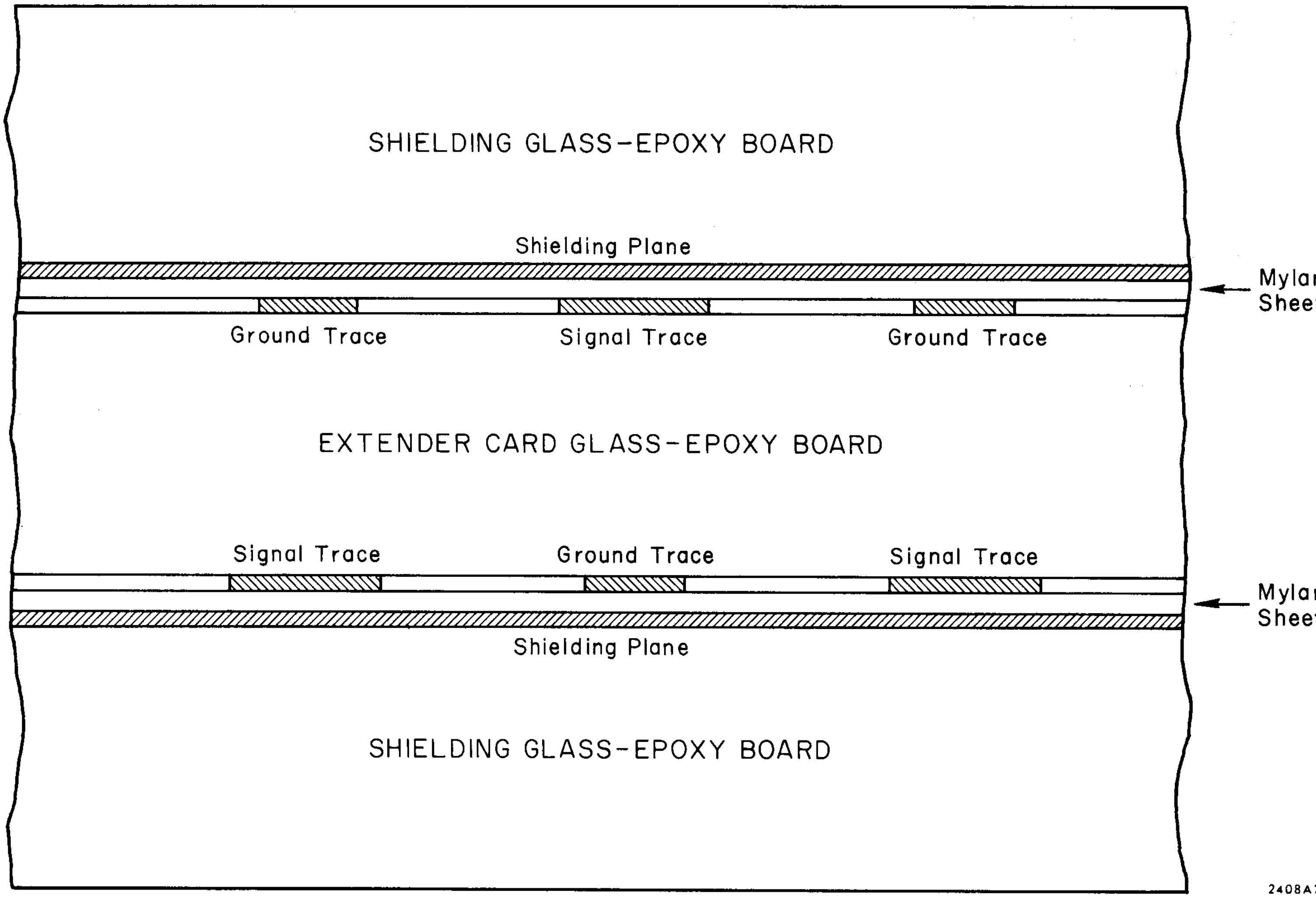


Figure 14: Extender Card, Artwork



TYPICAL DIMENSIONS (mm)

Trace Width – Signal 0.9
Trace Width – Ground 0.6
Trace Separation 1.25

Thickness – Glass-Epoxy Board 1.6
Thickness – Trace, Plane 0.075
Thickness – Mylar Sheet 0.13

Figure 15: Extender Card – Typical Cross Section

STANFORD LINEAR ACCELERATOR CENTER	DATE 7-23-73
DRAWING LIST FOR General Purpose PC Boards	PREPARED BY H. Walz CHECKED BY H. Walz APPROVED BY H. Walz 8-1-73

☐ MECHANICAL ☐ ARCHITECTURAL/CIVIL ☒ ELECTRICAL/ELECTRONICS

NO.	DOCUMENT NO.					TITLE OR DESCRIPTION	QUAN.
	PREF	BASE	SUFF	REV	SIZE		
1	GP	910-010	41			Card File Backplane - Artwork (2 sheets)	
2	GP	910-010	42			Card File Backplane - Drill Schedule	
3	SD	910-010	06			Card File Backplane - Digital Vcc Regulator, Circuit and Loading Diagram	
4	GP	910-010	46			PC Card Type "A" (28 DIP) IC Wirewrap, Artwork	
5	GP	910-010	47			PC Card Type "A" (28 DIP) Drill Schedule	
6	GP	910-010	48			PC Card Type "B" (28 DIP) IC Wirewrap, Artwork	
7	GP	910-010	49			PC Card Type "B" (28 DIP) Drill Schedule	
8	GP	910-010	42			IC Wirewrap Card "C", Artwork (44 DIP)	
9	GP	910-010	44			IC Wirewrap Card "C", Drill Schedule (44 DIP)	
10	GP	910-010	51			IC Wirewrap Board "D" (98 DIP) Artwork	
11	GP	910-010	52			IC Wirewrap Board "D" (98 DIP) Drill Schedule	
12	GP	910-010	67			File Power Input Card, Artwork	
13	GP	910-010	72			File Power Input Card, Drill Schedule	
14	GP	910-010	09			Voltage Plane Board Artwork and Drill Schedule	
15	GP	910-011	47			Card Extender Artwork (2 sheets)	
16	GP	910-011	48			Card Extender Drill Schedule	
17	SA	910-011	49			Card Extender Assembly Drawing	

REV	DESCRIPTION	DRN	CHK	APP	DATE

Figure 16

DL — 910-011-37-R0

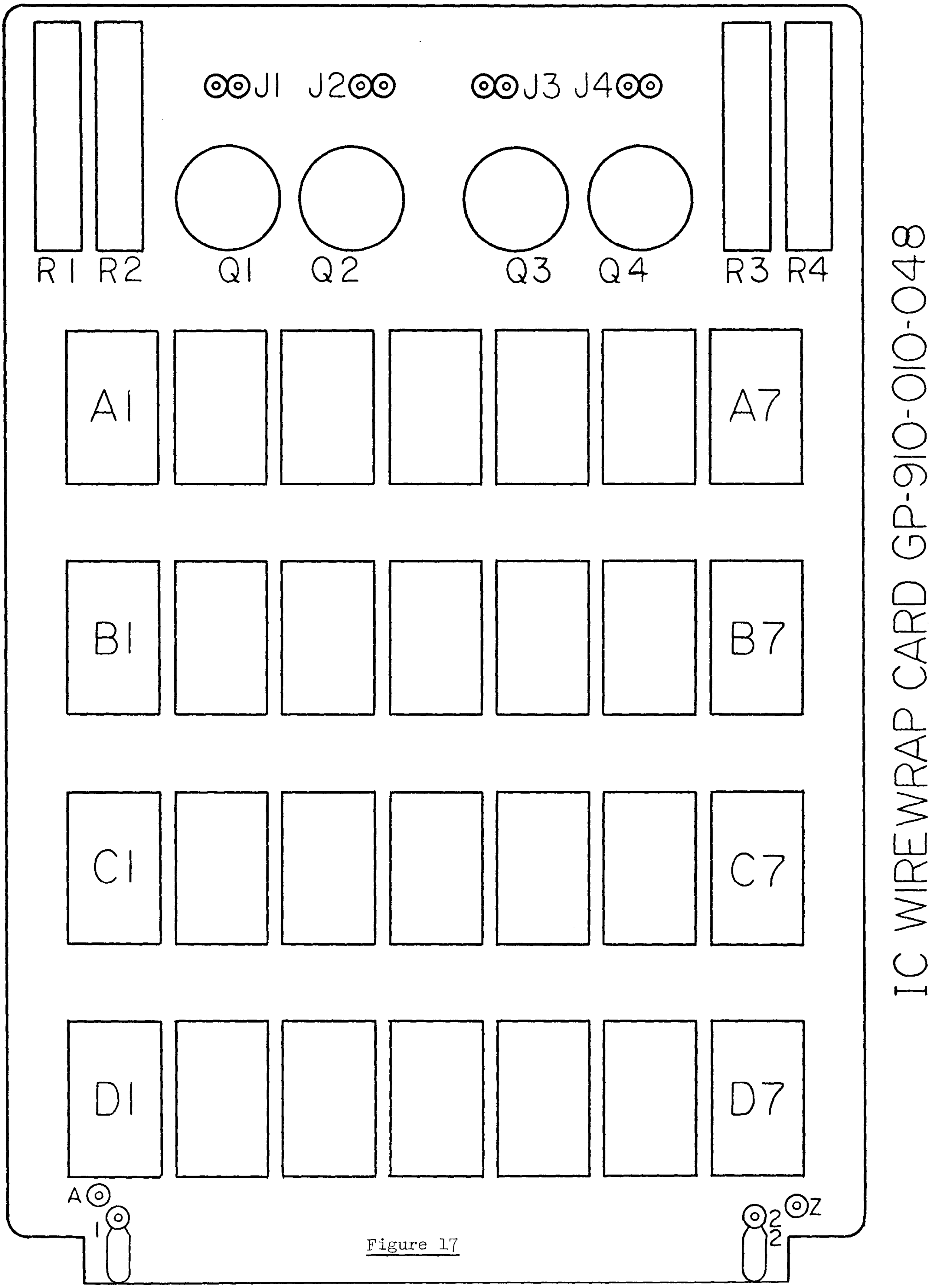

J1 J2 J3 J4
R1 R2 Q1 Q2 Q3 Q4 R3 R4
A1 A7
B1 B7
C1 C7
D1 D7
A 1 2 Z
IC WIREWRAP CARD GP-910-010-048

Figure 17