D/A VOLTAGE CONVERTER CARD

MODEL 69321B

OPERATING AND SERVICE MANUAL

FOR CARDS DESIGNATED RUN 1 AND ABOVE*

*For Cards above Run 1
a change page may be
included.

HP Part No. 69321-90003

December: 1972

TABLE OF CONTENTS

MANUAL CHANGES

Model 69321B D/A Voltage Converter Card
Manual HP Part No. 69321-90003

Make all corrections in the manual according to the errata below, then check the following table for your card's run or serial number and enter any listed change(s) in the manual.

RUN NUMBER		MAKE CHANGES
All		Errata
3		1
4 and above		1, 2
SERIAL		
Prefix	Number	
1519A	00241-00300	1, 2, 3
1519A	00301-00420	1 thru 4
1609A	00421-00780	1 thru 5
1638A	00781-01290	1 thru 6
1708A	01291-01910	1 thru 7
1805A	01911-up	1 thru 8

ERRATA:

In Table 1-1, change the ACCURACY specification to: ±5.0mV at 25°C ±5°C (card ambient when delivering 0.5mA). Change the TEMPERATURE COEFFICIENT specification to: ±600µV/°C from 15°C to 55°C card ambient, measured between ambient end points. ±1mV/°C from 55°C to 70°C card ambient, measured between ambient end points.

On page 3-5, change the paragraph heading from "69370A's" to "69321B's".

Since the accuracy specification has been changed to ±5.0mV, change the NORMAL INDICATION readings in Table 5-2 (Tests 3-6) to ±5.0mV (i. e. the NORMAL INDICATION for Test 4 is +5.12V ±5.0mV).

CHANGE 1:

On the 69321B schematic and parts list, change R31 and R33 to 51.1k 1% 1/8W, HP Part No. 0757-0458. This is a nominal value; the actual values are selected to center the adjustment of R32 and R34.

CHANGE 2:

On the 69321B schematic and parts list, change R36 to 100 ohms, HP Part No. 2100-1450. Also add resistor R40, 243 ohms 1% 1/8W HP Part No. 0757-0408. R40 has been added in series with R36, between R36 and the line that connects Z13A pin 23 with Z13B pin 17. This is a nominal value for R40, which is selected to center the adjustment of R36.

ERRATA:

In the parts list, change the part number for the 16-pin IC socket to 1200-0507 and the 14-pin IC socket to 1200-0508.

CHANGE 3:

In the parts list, delete D/A converter Z13A (1813-0012) and change the part number for Z13B from 1813-0027 to 5080-1841. This new part number is for a pretested D/A converter. Delete the calibration procedure of paragraph 5-25; the correct procedure for the 5080-1841 converter is in paragraph 5-26.

CHANGE 4:

In the parts list, change the part number for Z12 to 1826-0059.

CHANGE 5:

On page 1-1, add the following at the end of paragraph 1-2: "Effective 12/75, the 69351A Voltage Regulator Card is replaced by Model 69351B which provides more accurate ±15V power to the 69321B. The 69351B is covered in a separate Operating and Service Manual, HP Part No. 69351-90002".

On page 3-1, add the following to the CAUTION notice after paragraph 3-5:

CAUTION

All 69321B cards are shipped from the factory with jumpers installed selecting the 750mA supply. The LO side of the 69321B card's analog voltage output is tied to the common connection of its ±15V supply. Because the LO side of a 69370A card's analog current output is tied to its −15V supply input, 69321B and 69370A cards should not be powered from the same ±15V supply unless the external circuits connected to the outputs of the two types of cards are isolated from each other. Another limitation to combining 69321B cards with others on the same ±15V supply occurs when a 69421A card's digital output common line is grounded externally. Combining 69321B cards and the digital output circuits of 69421A cards will ground the 69321B card's LO output. In applications where the output signal common of 69321B cards must be isolated from the input or output signal common lines of any other D/A or A/D converter cards, separate ±15V supplies must be selected.

ERRATA:

In Figure 7-1 (Chapter 1), indicate that pins 9 and 5 are the Q outputs and pins 8 and 6 are the $\overline{Q}$ outputs of flip-flops Z6 through Z11 (Second Level Storage Circuit).

On page 6-6, add Mfr. Part No. "SN74L74N" for Z6-Z11.

CHANGE 6:

The serial number prefix of the Model 69321B has been changed to 1638A. This is the only change.

ERRATA:

On the Figure 7-1 schematic, change the value of R12 (at the address gate output) to 1.5kΩ.

CHANGE 7:

The D/A Converter module (Z13) has been changed to a new type (HP Part No. 1813-0094) and the D/A Converter and Operational Amplifier circuits have been redesigned. Substitute the accompanying partial schematic, partial component location diagram, and complete board parts list for those in the manual. Also substitute the following for steps f through j of the par. 5-25 calibration procedure. (Use the corrected par. 5-25 procedure, and disregard the one given in par. 5-26).

f. Program –10.24V and transmit to 69321B card as follows:

(1) Touch CLEAR REGISTER
(2) Select slot address (bits 15 through 12 to slot address.)
(3) Program –10.24V (bit 11 on, bits 10 through 0 off)
(4) Touch LOAD OUTPUT

g. Adjust potentiometer R36 for –10.24V ±1mV indication on the DVM.

h. Program +10.235V as follows:

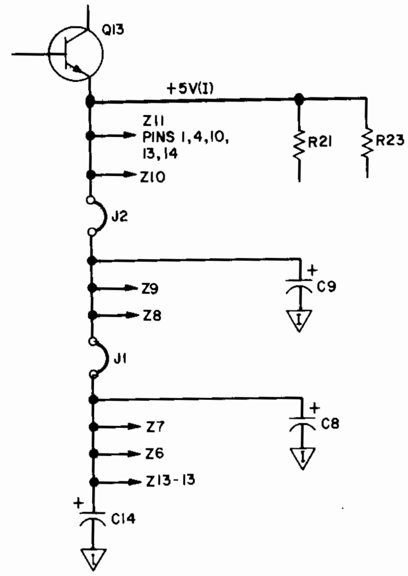
(1) Retain slot address
(2) Select +10.235V (bit 11 off; bits 10 through 0 on)
(3) Touch LOAD OUTPUT

i. Adjust potentiometer R32 for +10.235V ±1mV indication on the DVM.

j. Repeat the checkout procedure. Table 5-2, to verify programming accuracy.

The two new jumpers, J1 and J2, are for troubleshooting the +5V (I) supply and its loads, and are connected as shown.

The card's power requirements are increased to 75mA at +15 volts and 35mA at –15 volts. Correct Table 1-1 accordingly, and correct par. 1-6 and 3-5 to indicate that a 750mA output of a voltage regulator card can operate up to ten 69321B's and a 150mA output can operate up to two 69321B's



+5V (I) distribution
Part of Change 7

The old DAC module consisted of a 0 to 2mA source and a –1mA offset sink; the new module is a –2mA to 0mA sink and a 1mA offset source. This change does not affect the operation of other circuits on the card external to the DAC module, but current directions and polarities given in Fig. 4-2 and in par. 4-12 through 4-17 are no longer correct.

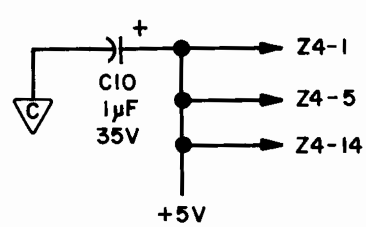
The old DAC modules (1813-0012, 1813-0027, or 5080-1841) cannot be used on the new card, or vice versa.

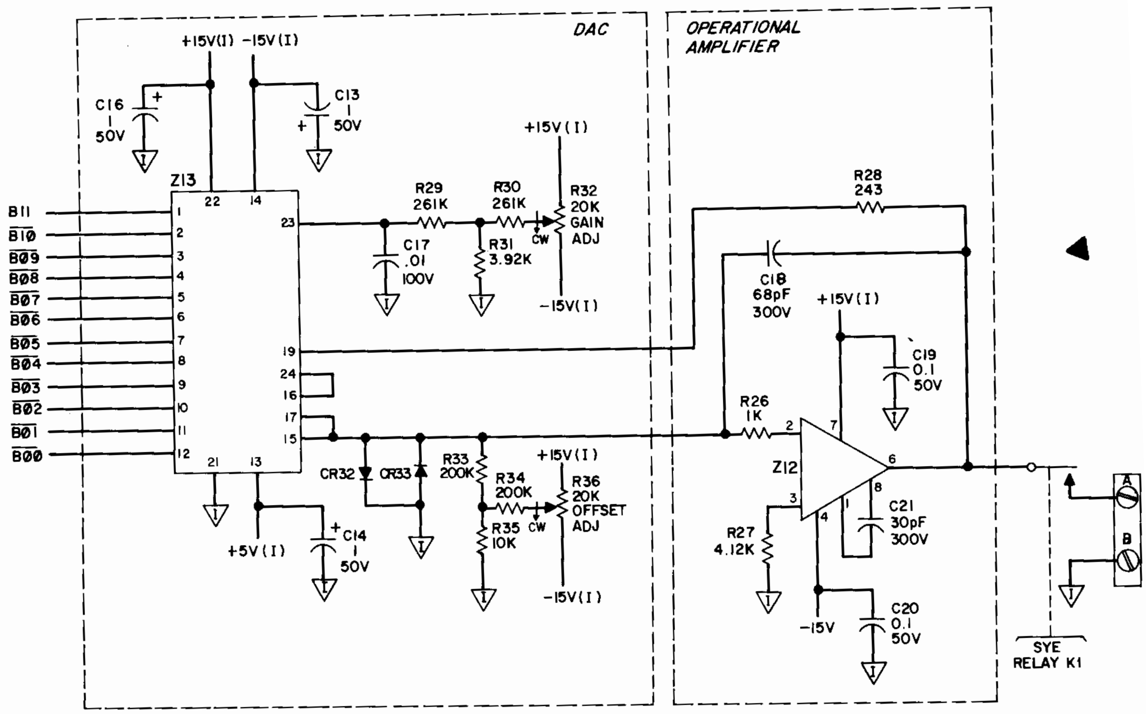
ERRATA:

In the parts list, delete the packing carton or corrugated tray listed and add the part number of the carton with foam liner now used for shipping multiprogrammer cards. Its number is 9211-2603.

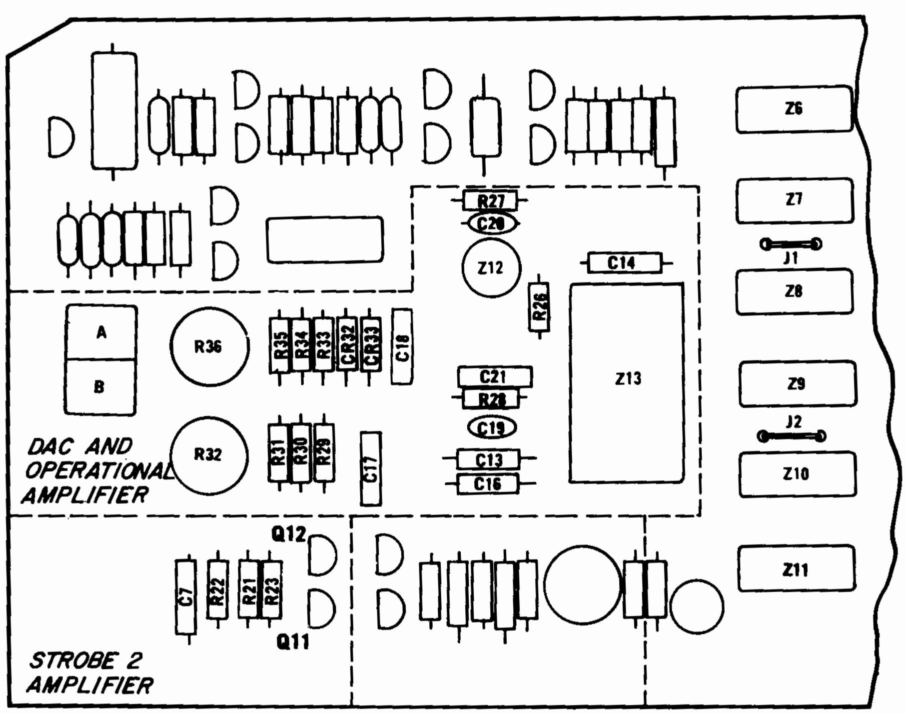
▶ CHANGE 8:

On page 4 of this change sheet, change capacitors C13, 14, 16, to 1μF 35V HP Part No. 0180-0291. Also on page 4, change C16 designation to C22. On Figure 7-1 in the manual, change C10 description to C16. Add capacitor C10 as shown below.





69321B Partial Schematic
(Part of Change 7)



69321B Partial Component Location Diagram
(Part of Change 7)

(Part of Change 7)
Table 6-4. Replaceable Parts, Model 69321B D/A Voltage Converter Card

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
A4 C1	fxd, mylar 0.001μF 200Vdc	6	192P10292	56289	0160-0153	2
C2	fxd, mylar 0.0022μF 200Vdc	1	292P33392	56289	0160-0154	1
C3-7	fxd, mylar 0.001μF 200Vdc		192P10292	56289	0160-0153	
C8-12	fxd, elect. 1.0μF 35Vdc	6	150D105X9035A2	56289	0180-0291	2
C13, 14	fxd, elect. 1.0μF 50V	3	150D105X0050A2	56289	0180-0230	1
C15	fxd, elect. 1.0μF 35V		150D105X9035A2	56289	0180-0291	
C16	fxd, elect. 1.0μF 50V		150D105X0050A2	56289	0180-0230	
C17	fxd, cer. 0.01μF 100V	1	OBD	05510	0150-0093	1
C18	fxd, mica 68pF 300V	1	OBD	04522	0140-0192	1
C19, 20	fxd, cer. 0.1 50V	2	5CY5U104D8050C5C	04200	0150-0121	1
C21	fxd, mica 30pF 300V	1	OBD	04522	0160-2199	1
CR 1-24	Diode, Si. 250mW 200V	31		28480	1901-0033	10
CR25	Stabistor, Si. 10prv	2		28480	1901-0460	2
CR26-30	Diode, Si. 250mW 200V			28480	1901-0033	
CR31	Stabistor, Si. 10prv			28480	1901-0460	
CR32, 33	Diode, Si. 250mW 200V			28480	1901-0033	
J1, 2	jumpers			28480	8151-0013	
K1	Relay, reed, 1 form A 12Vdc	1		28480	0490-0399	1
Q1	SS NPN Si.	12		28480	1854-0717	7
Q2	SS NPN Si.	2	2N3390		1854-0202	2
Q3-5	SS NPN Si.			28480	1854-0717	
Q6	SS NPN Si.		2N3390		1854-0202	
Q7-9	SS NPN Si.			28480	1854-0717	
Q10	SS NPN Si.	2		28480	1854-0271	2
Q11-12	SS NPN Si.			28480	1854-0717	
Q13	SS NPN Si.			28480	1854-0271	
Q14-16	SS NPN Si.			28480	1854-0717	
R1	fxd, comp 1.5k 5% 1/4W	2	CB1525	01121	0683-1525	1
R2	fxd, comp 3k 5% 1/4W	5	CB3025	01121	0683-3025	1
R3	fxd, comp 10k 5% 1/4W	1	CB1035	01121	0683-1035	1
R4	fxd, comp 1k 5% 1/4W	2	CB1025	01121	0683-1025	1
R5	fxd, comp 20k 5% 1/4W	2	CB2035	01121	0683-2035	1
R6	fxd, comp 200 5% 1/4W	2	CB2015	01121	0683-2015	1
R7	fxd, comp 680 5% 1/4W	1	CB6815	01121	0683-6815	1
R8	fxd, comp 200 5% 1/4W		CB2015	01121	0683-2015	
R9	fxd, comp 20k 5% 1/4W		CB2035	01121	0683-2035	
R10	fxd, comp 2k 5% 1/4W	2	CB2025	01121	0683-2025	1
R11	fxd, comp 510 5% 1/4W	1	CB5115	01121	0683-5115	1
R12	fxd, comp 1.5k 5% 1/4W		CB1525	01121	0683-1525	

(Part of Change 7 Continued)

Table 6-4. Replaceable Parts, Model 69321B D/A Voltage Converter Card

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
R13	fxd, comp 1k 5% 1/4W		CB1025	01121	0683-1025	
R14-17	fxd, comp 3k 5% 1/4W		CB3025	01121	0683-3025	
R18	fxd, comp 120 5% 1/4W	1	CB1215	01121	0683-1215	1
R19	fxd, comp 300 5% 1/4W	1	CB3015	01121	0683-3015	1
R20	fxd, comp 100 5% 1/4W	1	CB1015	01121	0683-1015	1
R21-22	fxd, comp 4.7k 5% 1/4W	2	CB4725	01121	0683-4725	1
R23	fxd, comp 7.5k 5% 1/4W	1	CB7525	01121	0683-7525	1
R24	fxd, film 10.1k 1% 1/4W	1	Type CCA T-0	07716	0757-0141	1
R25	fxd, film 7.5k 1% 1/8W	1	Type CEA T-0	07716	0757-0440	1
R26	fxd, film 1k 1% 1/8W	1	CEA-993	02273	0757-0280	1
R27	fxd, film 4.12k 1% 1/8W	1	CEA-993	02273	0698-3493	1
R28	var, film 243 1% 1/8W	1	MF4C-1	02995	0757-0408	1
R29-30	fxd, film 261k 1% 1/8W	2	MF4C-1	02995	0698-3455	1
R31	fxd, film 3.92k 1% 1/8W	1	MF4C-1	02995	0757-0435	1
R32	var, ww 20k 5% 1W	2	CT-100-4	07716	2100-1777	1
R33, 34	fxd, film 200k 1% 1/8W	2	MF4C-1	02995	0757-0472	1
R35	fxd, film 10k 1% 1/8W	1	MF4C-1	02995	0757-0442	1
R36	var, ww 20k 5% 1W		CT-100-4	07716	2100-1777	
R37	fxd, comp 2k 5% 1/4W		CB2025	01121	0683-2025	
R38	fxd, comp 5.1k 5% 1/4W	1	CB5125	01121	0683-5125	1
R39	fxd, comp 51k 5% 1/4W	1	CB5135	01121	0683-5135	1
T1-13	Transformer, signal	13		28480	69370-80091	3
Z1-3	Quad Bistable Latch, IC	3	SN74L75N	01295	1820-0876	3
Z4	8-input NAND Gate, IC	1	SN7430N	01295	1820-0070	1
Z5	Quad 2-input NAND Gate, IC	1	SN7400N	01295	1820-0054	1
Z6-11	Dual D-type flip-flop, IC	6	SN74L74N	01295	1820-0596	6
Z12	Operational Amplifier, IC	1	LM201AH	03406	1826-0059	1
Z13	DAC Module, IC	1	DAC 80-CBI-I	05436	1813-0094	1
Z14	Quad 2-input NAND Gate, IC	1	SN12955	27014	1820-0583	1
	MECHANICAL					
	Terminal Block, TB1	1		28480	0360-1602	1
	Extractor Handle, Marked	1		28480	5081-4915	
	Tray, Corrugated	1		28480	9220-1419	

SECTION I
GENERAL INFORMATION

1-1 INTRODUCTION

1-2 This instruction manual contains operating and service instructions for the Model 69321B D/A Voltage Converter Card. This card is designed specifically for use in the 6940B Multiprogrammer Extender units. Overall system concepts including system installation, trouble shooting, and operating considerations are covered in the instruction manuals for the 6940B unit and are not repeated in this manual. Programming information for use with calculator-based multiprogrammer systems can be found in two Hewlett Packard Interface Bus User's Guides. One of them (manual part number 59500-90003) covers calculator Models 9820A, 9821A, and 9830A; and the other (manual part number 59500-90005) covers the Model 9825A Calculator.

1-3 DESCRIPTION

1-4 The 69321B 12-Bit D/A Converter Card provides a bipolar voltage output that is proportional to programmed digital data. The output voltage range is from -10.240V to +10.235V with a minimum programmable step change of 5mV. Positive output levels from 0 to +10.235V are programmed in straight binary form, while negative levels from -5mV to -10.240V are programmed in 2's complement form. The ground (COM) line of the programmed output voltage is isolated from the mainframe grounds.

1-5 The 69321B is fabricated on a 4-1/2" x 11" printed circuit card. The inner end of the card contains a dual 24 pin (48 pin total) printed circuit plug that can mate with any connector in slots 400 through 414 of a multiprogrammer unit. The programmed voltage output is taken from a terminal block located on the outer-end of the card.

1-6 When installed in a Multiprogrammer System, the 69321B is programmed by a 16-bit word originating at a remote computer or the 6936A/6940A Multiprogrammer control panel. Eleven of the programmed bits ($\overline{B00}$ through $\overline{B10}$) represent the magnitude of the output voltage; one bit ($\overline{B11}$) represents the sign of the output voltage; and four bits (B12/$\overline{B12}$ through B15/$\overline{B15}$) represent the slot address of the output card.

1-7 When the card is addressed and strobed, the sign and magnitude bits are stored in an input (first level) storage register. Then, if the data transfer enable (DTE) mode is programmed on, the stored data is transferred through a set of isolation transformers to an output (second level) storage register. At this point, the stored sign and magnitude bits are applied to a D/A voltage converter which generates an output voltage proportional to the programmed digital data. Specific programming information and circuit descriptions are provided in Sections III and IV respectively, of this Chapter.

1-8 ISOLATED BIAS VOLTAGES

1-9 Voltage Regulator Card Model 69351B is required for use with D/A Voltage Converter cards and is installed in slot 600 of any unit utilizing a 69321B. The voltage regulator card contains four isolated + and -15 volt regulated supplies; one of the supplies has a 750mA output (capable of operating up to fifteen 69321B's) while the remaining three can supply up to 150mA each (power for up to three 69321B's). The regulated outputs of the four supplies are wired to all 400 series slot connectors and are available to the 69321B card when it is plugged into a 400 series slot. Jumper connections must be made on the 69321B card to select one of the four isolated supplies four isolated supplies for use by the particular D/A converter card. (As supplied from the factory, the ±15 volt supply is selected by jumper connections.) Refer to Section III for complete coverage of the ±15 volt jumper options.

1-10 SPECIFICATIONS

1-11 Table 1-1 provides detailed specifications for the Model 69321B.

1-12 INTERFACING

1-13 Any accessory card can be installed in any series slot of a Multiprogrammer or Extender unit. Once an accessory card is assigned to a slot, it assumes the address of that position and will receive programmed data only when the applicable unit and slot are addressed. All operating power and programming bits for the accessory cards are derived from the multiprogrammer mainframe unit.

1-14 The programmed voltage output of the card is taken from a terminal block on the outer -end of the card and wired to the external system.

1-15 One of the four isolated ±15 volt supplies available to the 69321B when it is plugged into a 400 series multiprogrammer slot must be selected by jumper connections on the 69321B card. Detailed instructions for performing the jumper connections are provided in Section III.

1-16 ORDERING ADDITIONAL MANUALS

1-17 One manual is shipped with each order. Additional manuals may be purchased from your local Hewlett-Packard field office (see list at rear of this manual for addresses). Specify the card model number, and HP Part Number shown on the title page.

Table 1-1. Model 69321B Specifications

DATA INPUT:
12 bit binary (11 data bits and 1 sign bit). Positive values are programmed in straight binary form; negative values are programmed in 2 s complement form.

OUTPUT:
-10.240V to +10.235V, with through zero programming.

MINIMUM STEP CHANGE:
5mV.

ACCURACY:
±5.0mV at 25°C ±5°C (card ambient) when delivering 0-5mA.

PROGRAMMING SPEED:
Digital data transfer to card: approximately 10μsec. Analog voltage conversion: 30μsec maximum for a 0 to± full scale change (to within 5mV of final value).

TRANSIENTS:
Essentially free of programming transients.

LOAD REGULATION:
3mV maximum at output terminals when delivering 0-5mA.

RIPPLE AND NOISE:
2mV p p maximum (dc to 400kHz).

TEMPERATURE COEFFICIENT:
±600μV/°C from 15°C card ambient, measured between ambient end points.
±1mV/°C from 55°C to 70°C card ambient, measured between ambient end points.

STABILITY:
1.5mV maximum total drift for 24 hours after 1/2 hour warm up.

POWER REQUIREMENTS:
+15Vdc at 50mA maximum. Power supplied by Voltage Regulator Card.
-15Vdc at 20mA maximum. Power supplied by Voltage Regulator Card.
+12Vdc at 10mA maximum from Multiprogrammer Main Power Supply.
+5Vdc at 200mA maximum from Multiprogrammer Main Power Supply.

OUTPUT PROTECTION:
Can withstand indefinite short circuit.

BREAKDOWN VOLTAGE:
Potential difference between any one output terminal and chassis ground must not exceed 100Vdc.

TEMPERATURE RANGE:
0°C to +70°C operating mainframe (allows +15°C internal rise when operating in mainframe at up to +55°C ambient); -40°C to +80°C storage.

OPERATING POSITION:
Any (no restrictions).

SYSTEM ENABLE FUNCTION:
Output line is held open by set of relay contacts until system enable bit is programmed and card is addressed and strobed at least once.

OUTPUT TERMINALS:
Two-contact terminal block (size 6 spade).

DIMENSIONS:
4.5" x 11.0" nominal.

WEIGHT:
0.7 lbs.

SECTION II
INSTALLATION

2-1 INITIAL INSPECTION

2-2 Before shipment, the 69321B 12-Bit D/A Voltage Converter Card was inspected and found to be free of mechanical and electrical defects. As soon as the card is received, proceed as instructed in the following paragraphs.

2-3 MECHANICAL CHECK

2-4 If external damage to the shipping carton is evident, ask the carrier's agent to be present when the card is unpacked. Check the output card for signs of physical damage. If it is damaged, file a claim with the carrier's agent and notify Hewlett-Packard Sales and Service Office as soon as possible. If it appears to be undamaged, perform the electrical check referenced in the following paragraph.

2-5 ELECTRICAL CHECK

2-6 Check the electrical performance of the output card as soon as possible after receipt. Section V of this Chapter contains checkout procedures, which will verify operation of the output card. Refer to the inside front cover of this manual for Certification and Warranty statements.

2-7 REPACKING FOR SHIPMENT

2-8 When shipping an output card, it is recommended that the package designed for it be used. The original packaging material is reusable. If it is not available, contact your local Hewlett-Packard field office to obtain the materials. This office will also furnish the address of the nearest service office to which the output card can be shipped. Be sure to attach a tag to the output card specifying the owner, model number, and service required, or a brief description of the trouble.

2-9 ±15 VOLT JUMPER CONNECTIONS

2-10 Procedures for selecting one of the four +15 and -15 volt isolated supplies available on each 12-bit D/A voltage converter card, and related operating considerations, are provided in Section III of this Chapter.

2-11 OUTPUT CARD INSTALLATION

CAUTION

Always turn off power at the multiprogrammer before installing or removing the output card. If power is not removed, it is possible to short components in the multiprogrammer when installing or removing a card, thereby causing possible damage.

2-12 Output cards are installed in slots 400 through 414 of a multiprogrammer unit. To install an output card, proceed as follows:

a. Open the hinged front panel of the multiprogrammer unit by turning the recessed screw within the knurled handle counterclockwise.

b. With the extractor handle on the top and the card components on the right, slide the card into the desired output slot (400 through 414). Note that all output cards are slotted between pins 4 and 5 and all 400 series connectors of the multiprogrammer are keyed between the same points. This makes it virtually impossible to plug an output card in upside down or into any slot other than a 400 series slot.

c. Route all wiring from the output cards through the false-bottom channel and out the back of the unit to the external system. Special wiring considerations are covered in Section III of this Chapter.

d. As physical installation and wiring are completed for each output card, carefully note and record the following types of information on the installation record card located on the rear of the hinged front panel of the multiprogrammer.

(1) Output card type.
(2) Application in external system.
(3) Ranges, scaling factors, etc.

2-13 CALIBRATION

2-14 Calibration procedures for the 69321B are provided in Section V.

SECTION III
OPERATING INSTRUCTIONS

3-1 DATA INPUTS

3-2 The 69321B D/A voltage converter card is controlled by the multiprogrammer unit in which it is installed. All dc operating power, address and data bits, and control signals are supplied to the output cards through the multiprogrammer mainframe connectors in slots 400 through 414. Figure 3-1 illustrates the signals present on the multiprogrammer 400-series connector.

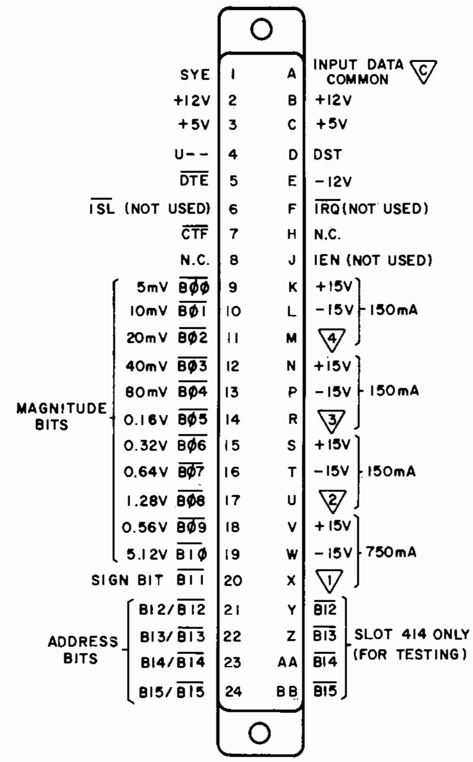


Figure 3-1. Multiprogrammer 400 Series Slot Connector

3-3 ±15 VOLT JUMPER CONNECTIONS

3-4 As shown in Figure 3-1 and the component location diagram of Figure 7-1, four ±15 volt power sources are available to the 12-bit D/A voltage converter when it is plugged into a 400 series multiprogrammer slot connector. The four supplies are isolated from one another and from the multiprogrammer main power supply.

3-5 One of the supplies must be selected by jumper connections on the card to provide power for the output storage and D/A conversion circuits of the 69321B. Each of the three 150mA ± 15 volt supplies can provide operating power for up to two 69321B's; the 750mA supply can provide power for up to ten 69321B's. (All 69321B cards are shipped from the factory with the 750mA supply selected; this connection should be changed, as necessary.) The COM (ground) of the selected ± 15 volt supply will become the COM for the programmed output voltage. Therefore, in applications where the output signal COM of a card must be isolated from all other COM's, only the one card may be operated from the selected supply. Where COM isolation is not required, the 750mA supply can be used to power up to ten 69321B's.

CAUTION

The current and ground isolation requirements of other model D/A cards in the same mainframe as the 69321B must be considered in determining the quantity of D/A cards in the mainframe. Also, when connecting the ±15V jumpers for a 69321B card consider the connections utilized (if any) for 69370A cards in the same mainframe (the output of the 69370A is referenced to -15V).

3-6 PROGRAMMING

3-7 The programming information presented here defines the relationships between programmed data and the 69321B card outputs. Complete system programming instructions are given in the Operating and Service Manual and the 6936A or 69340A Multiprogrammer.

3-8 There are four general steps involved in programming the 69321B. These steps (not necessarily in the normal programming sequence) are listed below:

a. Addressing the multiprogrammer unit and slot containing the output card.

b. Programming magnitude and sign bit data that will produce the desired voltage output.

c. Enabling the output card by programming the system enable (SYE) bit to a logical 1.

d. Programming the data transfer enable (DTE) mode, which will transfer the programmed data from the first level storage registers to the second level storage registers and the D/A conversion circuits.

3-9 It is assumed in the following discussion that the reader is familiar with the definitions and functions of multiprogrammer control and data words. If this is not the case, it is suggested that Section III of the 6936A or 6940A Instruction Manual be read before proceeding.

3-10 SYSTEM ENABLE

3-11 An SYE control line is wired to all multiprogrammer 400 series slot connectors. When the system enable function is programmed as part of a control word, the SYE line goes HI and if the card has been (or is subsequently) addressed (see next paragraph) energizes a relay on the output card. The SYE relay contacts couple the D/A converter output to card output terminal TB1-A. Prior to SYE or the card address being programmed on, the card output is held in an open circuit condition. The SYE control circuit is also activated and the card output disabled when multiprogrammer power is turned on or if the + 5V input power to the card falls below approximately + 4V.

3-12 ADDRESSING

3-13 An output card is selected to receive new data when its associated address bits (B12/$\overline{\text{B12}}$ through B15/$\overline{\text{B15}}$), a unit select line (U--), and the multiprogrammer data strobe (DST) are all HI. Although both the true and complemented forms of the address bits are represented on Figure 3-1 (e.g. B12 and $\overline{\text{B12}}$) only one of the two states is present on each of the four address gate lines when the card is installed in a multiprogrammer slot. For example, if the output card is installed in slot 405, then bits B12 (1), $\overline{\text{B13}}$ (2), B14 (4), and $\overline{\text{B15}}$ (8) will be present on the address lines; and all four lines will be HI when slot 405 is addressed. The U-- line is HI when the associated multiprogrammer unit is selected as part of a control word. The unit selection is stored by the master unit and it remains in effect until a different unit is selected by a later control word. The data strobe goes HI when the multiprogrammer receives the computer Gate input . Note that the card must be addressed and DST received at least once in order for the SYE relay (and, thus, the card output) to be energized when SYE is programmed on.

3-14 VOLTAGE PROGRAMMING

3-15 The 12-bit D/A voltage converter is programmed by magnitude bits $\overline{\text{BØØ}}$ (LSB) through $\overline{\text{B1Ø}}$ and sign bit $\overline{\text{B11}}$. When the card is addressed and data strobed, the 11-magnitude bits and the sign bit are stored in the first level storage registers. When DTE is programmed (or if DTE was in effect when the card was addressed and strobed) the data and sign bits are transferred to the second level storage registers and from there to the D/A conversion circuits.

3-16 PROGRAMMING POSITIVE LEVELS

3-17 Positive output voltage levels from 0 to + 10.235 volts are programmed in straight binary form. The output voltage level will be equal to the decimal equivalent of the programmed binary number, times 5mV. Sign bit $\overline{\text{B11}}$ is programmed to a binary 0 for positive values. Figure 3-1 illustrates the weight, in terms of positive output voltage, of each of the 11 magnitude bits. Table 3-1 lists some examples of the binary numbers required to program positive and negative output voltages and their decimals equivalents.

Table 3-1. Output Voltage Programming Data Format Examples

POSITIVE OUTPUT VOLTAGE			NEGATIVE OUTPUT VOLTAGE		
Voltage	Programmed Binary Value MSB (B11) LSB (BØØ)	Decimal Equivalent	Voltage	Programmed Binary Value	Decimal Equivalent
0	000000000000	0	–	–	–
5mV	000000000001	1	–5mV	111111111111	–1
5.12V	010000000000	1024	–5.12V	110000000000	–1024
10.235V	011111111111	2047	–10.235V	100000000001	–2047
–	–	–	–10.240V	100000000000	–2048
9.125V	011100100001	1825	–9.125	100011011111	–1825

3-18 PROGRAMMING NEGATIVE LEVELS

3-19 Negative levels from -5mV to -10.240V are programmed in 2's complement form; that is, except for the maximum negative value, the equivalent positive number is complemented (all ones become zeros, and all zeros become ones) and a binary one is added to the least significant bit. Note that because of the nature of 2's complementing, it is impossible to program for 0 volts output when the negative sign is selected. The lowest negative number that can be programmed is -5mV. Hence, to obtain an output of 0 volts, the sign must be positive. Sign bit $\overline{B11}$ is programmed to a binary 1 for negative values. For the maximum negative voltage, for which there is no positive equivalent, you must program only the sign bit on (i. e. -2048_{10}).

3-20 DATA TRANSFER ENABLE

3-21 The data transfer enable (DTE) mode is selected by programming bit 6 of a control word to a logical 1. When the mode is selected, the $\overline{DTE}$ input line of all the 69321B cards goes to the LO (active) state.

3-22 The DTE mode can be used in either of two ways on the 69321B to transfer data from the first level storage registers to the second level storage registers and from there to the output D/A conversion circuits:

(1) DTE is Selected and Held. With this method, each time a 69321B card is addressed and data strobed, the programmed data designated for that card is entered into the first level storage registers and immediately transferred to the second level registers and then to the output D/A conversion circuits. An addressed card will thus produce an analog output proportional to the programmed data, as it receives the data.

(2) DTE is Programmed After Cards are Addressed. This method permits the output of any number of 69321B cards to be changed to a new programmed value simultaneously. The timing diagram in Figure 3-2 illustrates this procedure. Cards 1, 2, and 3 are sequentially loaded with new data A, B, and C, respectively; card 4 is not addressed and consequently retains the old programmed value in its first level storage registers. Now, when DTE is programmed on, it transfers the first-level data to the second-level registers and from there to the D/A conversion circuits. For cards 1, 2, and 3, their analog outputs simultaneously change to the new value. For card 4 (and all other cards not addressed), the output value remains the same, since the old programmed value is simply re-transferred to the second level registers.

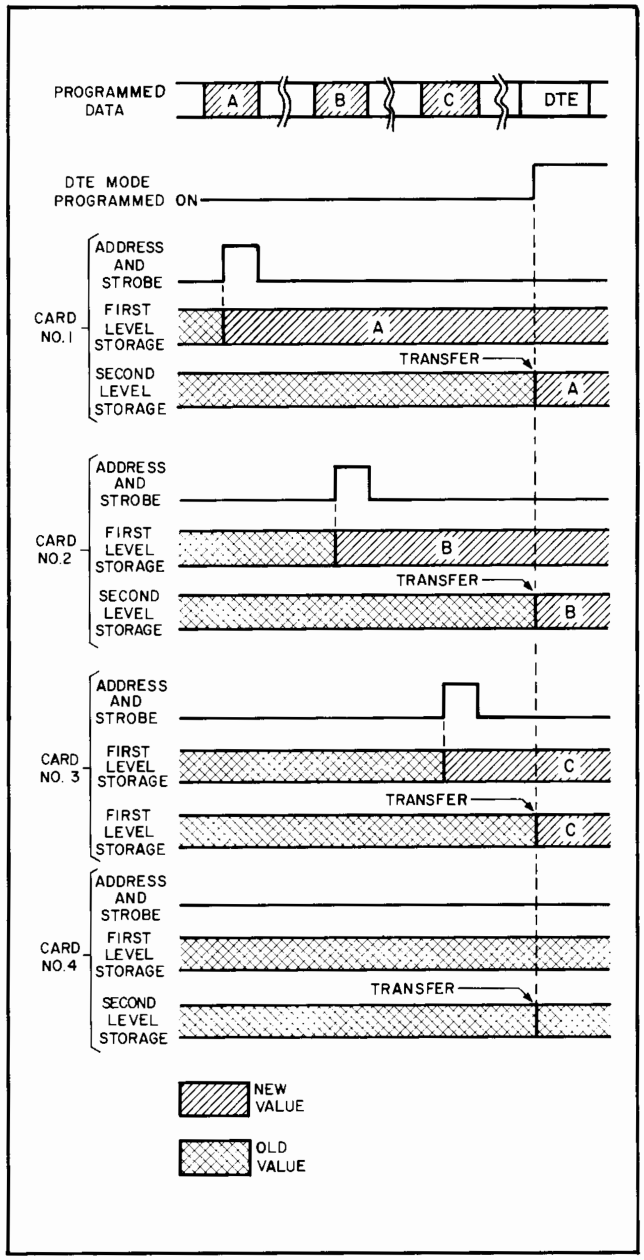


Figure 3-2. DTE Mode, Timing Diagram

3-23 COMMON TIMING FLAG

3-24 A timing flag circuit on each 69321B card produces a $\overline{CTF}$ pulse that starts when the programmed data is transferred to the D/A conversion circuits and lasts for approximately 30μsec. The purpose of $\overline{CTF}$ is to prevent the Multiprogrammer from inputting new data to the output card while it is still processing and converting its last data input. (Other $\overline{CTF}$ periods can be selected by altering the CTF circuit; see note 1 on figure 7-1.)

3-25 LOAD CONNECTIONS

3-26 The bipolar analog output of the 69321B is available across terminals A (SIG.) and B (COM) of terminal block TB1. The accuracy specifications of the output signal are guaranteed for loads up to 5mA; operation within specifications for loads up to 10mA is typical. To avoid overshoot, the load capacitance should be limited to 0.1μF.

3-27 Output connections bwtween the 69321B and the load should be kept as short as possible. Use of shielded cable or a twisted pair is recommended.

3-28 SAMPLE HP ASSEMBLY LANGUAGE PROGRAMMING

3-29 The following paragraphs provide simple examples of programming a 12-bit D/A voltage converter card in HP Assembly Language. The examples illustrate both ways in which DTE can be used during output card programming; that is, loading a 69321B after DTE is programmed on, or loading several 69321B cards before DTE is programmed on. In the first example, the data transferred to the card is stored in second level storage immediately and, as a result, the card processes the data for output. Of course, if SYE is also on (as it is in the example), the output of the card is also enabled. In the second example, on the other hand, the data sent to the addressed cards is transferred only to first level storage. Second level storage of the cards, and their outputs, are not enabled until DTE is programmed on (assuming, of course, SYE is already on). Thus, the outputs of all cards are updated simultaneously.

3-30 Notice that when programming the 69321B (and any multiprogrammer I/O card), the timing and system enable modes (TME and SYE) must also be specified. In the examples, TME is turned off whenever the 69321B is not expected to return its common timing flag ($\overline{CTF}$); that is, when the card is programmed before DTE is turned on. On the other hand, TME is programmed on to allow the card's $\overline{CTF}$ time period to expire before the program continues whenever the card is expected to return its $\overline{CTF}$ (i.e. when it is addressed and DTE is on). Importantly, note that the handshake flag is expected back each time a control word is programmed. This, of course, assumes that the program has not previously enabled an I/O card's $\overline{CTF}$ circuit. SYE, of course, must be programmed on to enable the output of the 69321B.

3-31 The sample programs are for illustration purposes and do not reflect the most efficient way in which to program the multiprogrammer. For instance, the program continually tests if the multiprogrammer is ready for another word by sensing its computer I/O card Flag. The computer's interrupt system could be utilized for this function by allowing the multiprogrammer program to be called via the interrupt system when the multiprogrammer is ready. Thus, the computer can be gainfully employed pursuing other system functions rather than tied up completely by the multiprogrammer channel.

3-32 Update 69321B Output Immediately.

	ASMB, R, B, L, T	
	NAM PROG1	Name of relocatable program.
		No previous I/O card CTFs timing out.
PROG1	LDA OTCW1	Load A Reg. with 170160_8; control word to set DTE, SYE, and TME on; select unit ØØ.
	OTA nn	Output control word to multiprogrammer.
	STC nn, C	Set multiprogrammer Gate, clear multiprogrammer Flag (on computer I/O card).
	SFS nn	Check if multiprogrammer ready for next word (I/O card Flag set).
	JMP *-1	Wait until ready.
	LDA OTDW1	Ready. Load A Reg. with data word for 69321B (includes slot address of 69321B).
	OTA nn	Output data word to 69321B.
	STC nn, C	Set multiprogrammer Gate, clear Flag.
	SFS nn	Check if multiprogrammer ready for next word.
	JMP *-1	Wait until 69321B times out.
OTCW1	OCT 17Ø16Ø	Control word assumes card is in unit ØØ
OTDW1	OCT ------	Data word; include card's slot address ($0\text{-}14_{10}$) and desired data (-2048 to 2047, i.e. -10.240V to 10.235V).
	END	

NOTE: "nn" in all instructions that address the multiprogrammer must be equal to the unit reference number assigned to the multiprogrammer. The unit reference number can be in the range $07_8 \leq$ unit reference number $\leq 77_8$.

3-33 Program Several 69321B's: Update Outputs Simultaneously.

	ASMB, R, B, L, T	
	NAM PROG2	Name of relocatable program.
		No previous I/O card CTFs timing out; SYE on.
PROG2	LDA OTCW2	Load A Reg. with $17ØØ4Ø_8$; control word to set SYE on, DTE and TME off; select unit ØØ.
	OTA nn	Output control word to multiprogrammer.
	STC nn, C	Set multiprogrammer Gate; clear Flag.
	SFS nn	Check if multiprogrammer ready for next word.
	JMP *-1	Wait until ready.
	LDA OTDW1	Ready. Load A Reg. with data word for first 69321B (include slot address).
	OTA nn	Output data word.
	STC nn, C	Set multiprogrammer Gate; clear Flag.
	SFS nn	Check if multiprogrammer ready for next word.
	JMP *-1	
	LDA OTDW2	Load A reg. with data word for second 69321B (include slot address).
	OTA nn	
	STC nn, C	
	SFS nn	
	JMP *-1	
	LDA OTDW3	Load A Reg. with data word for third 69321B (include slot address).
	OTA nn	
	STC nn, C	
	SFS nn	
	JMP *-1	
	LDA OTCW1	Load A Reg. with $17Ø16Ø_8$; control word to set DTE, SYE, and TME on; select unit ØØ.
	OTA nn	DTE updates all programmed cards and their outputs assume new values simultaneously
	STC nn, C	
	SFS nn	
	JMP *-1	Wait for cards' CTFs to time out before proceeding with program.
	⋮	
OTCW2	OCT $17ØØ4Ø_8$	Control word assumes cards are in unit ØØ.
OTDW1	OCT ------	Data word 1, include card's slot address ($0-14_{10}$)
OTDW2	OCT ------	and desired data.
OTDW3	OCT ------	
OTCW1	OCT $17Ø16Ø_8$	Control word (assumes unit ØØ).
	END	

See note at end of paragraph 3-32 for explanation of "nn"

SECTION IV
PRINCIPLES OF OPERATION

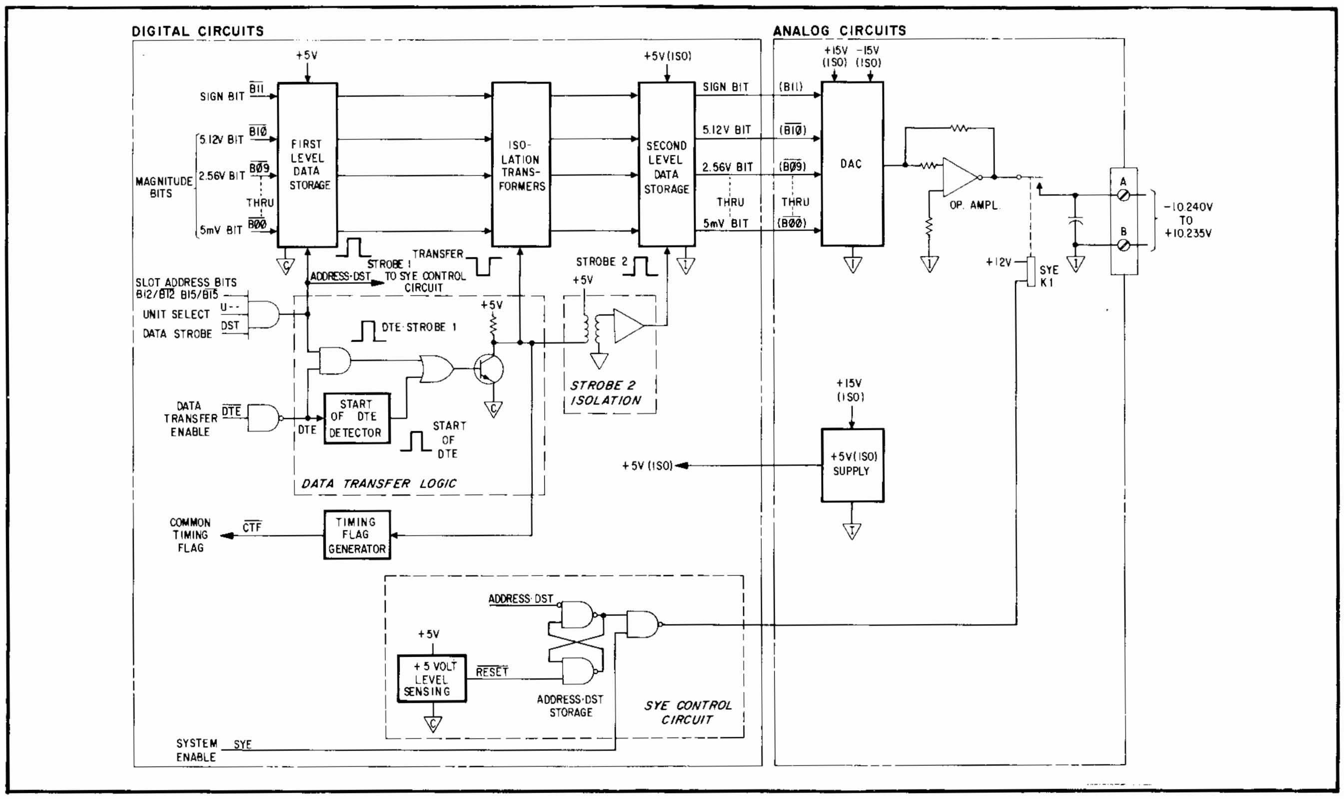


Figure 4-1. 12-Bit D/A Voltage Converter Card, Block Diagram

4-1 INTRODUCTION

4-2 This section contains principles of operation for the 69321B 12-Bit D/A Voltage Converter Card. Theory is presented on both a simplified block diagram and a detailed circuit theory level.

4-3 BLOCK DIAGRAM THEORY

4-4 As shown in Figure 4-1, the 12-Bit D/A voltage converter is comprised of two functional circuit groups; a digital circuit group and an analog group. Each group is covered separately in the following paragraphs. (Note that the logic circuits shown in Figure 4-1 express the logical operations in simplified form; the actual logic circuit implementation of these functions is shown schematically in Figure 7-1.)

4-5 DIGITAL CIRCUITS

4-6 The digital circuits receive and store programmed digital data when the card is addressed and strobed and, depending on the programmed state of the DTE mode bit, either retain the programmed data in the first level data storage registers only, or also transfer the data to the second level data storage registers.

4-7 The data transfer logic transfers programmed data through the isolation transformers to the second level data storage registers for either of two conditions: (1) DTE is programmed and held in the on state ($\overline{DTE}$, LO) and the card is later addressed and strobed; or (2) DTE makes a programmed transition from the off to the on state. Method (1) is used to produce an analog output proportional to the programmed data, as the card receives the data, and method (2) is used to produce a simultaneous output voltage change from a number of 69321B cards. (See Paragraph 3-20 for a more detailed operational description of these two methods.)

Once the data is in the second level registers it controls the current output of the D/A converter (DAC) module.

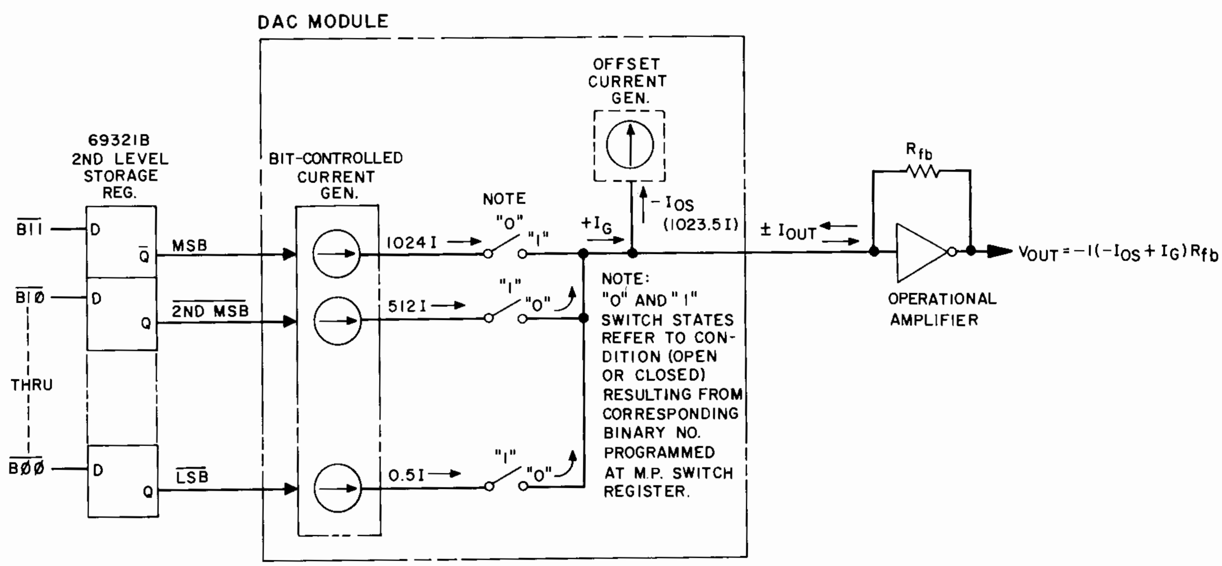
4-8 The digital circuits also include the SYE control circuit which is comprised of the + 5V level sensing circuit and an associated card address• DST storage circuit as well as the SYE relay. When power is applied to the multiprogrammer, the sensing circuit resets the card address•DST storage circuit which, in turn, resets SYE output relay K1. Thus, the card must be addressed with DST to set this circuit and, further, SYE must be programmed on to enable the SYE relay. Notice further, that if the + 5V input falls below approximately + 4V, the sensing circuit resets the storage circuit and, thereby, disables the output of the card (the SYE relay deenergizes).

4-9 ANALOG CIRCUITS

4-10 The analog circuits consist of a DAC module and associated operational amplifier. (Two DAC modules are shown on the schematic diagram, Figure 7-1, but only one of the two is ever installed on a 69321B card. While the two DAC's perform identical functions, they differ internally and require different calibration procedures as covered in Paragraph 5-23.)

4-11 The DAC module generates a binary-weighted current in the range of -1mA to + 1mA, whose magnitude and sign are a function of the digital data stored in the second level register. The DAC output current is applied to an operational amplifier which converts the current to a proportional output voltage in the range of -10.240V to + 10.235V.

4-12 As shown in Figure 4-2, the DAC module is essentially made up of 12 current generators, each controlled by an associated data bit ($\overline{\text{B}\emptyset\emptyset}$ through $\overline{\text{B}1\emptyset}$) or sign bit (B11), and a fixed offset current generator. When a particular data bit is programmed to a binary "0" at the computer or the multiprogrammer switch register, the associated current generator is switched on and produces an output current in proportion to the binary-weight of the bit. When the same bit is programmed to a binary "1", the associated current generator is switched off. (The sign bit is inverted prior to its application to the DAC so that a programmed binary "0"



SAMPLE: BIT/LOGIC LEVEL STATES FOR PROGRAMMED +10.235V OUTPUT

BIT	BINARY NO. (2047_{10} = +10.235V)	MP BACKPLANE	DAC INPUT	CURRENT GEN.	OUTPUT EQUATION FOR +10.235V
$\overline{\text{B11}}$/MSB (SIGN)	0	HI	LO	OFF	$-I_{OS}$
$\overline{\text{B}1\emptyset}$ THRU $\overline{\text{B}\emptyset\emptyset}$/LSB	1	LO	LO	OFF	$V_{OUT} = -I(-1023.5I+0)R_{fb}$ $= +1023.5\ I \times R_{fb}$ $= +10.235V$

Figure 4-2. D/A Conversion Circuits, Functional Block Diagram

switches off the current generator.) The outputs of all the "on" generators are summed together and then are further summed with the fixed offset current. The current resulting from all the summations flows through the feedback resistor of the operational amplifier to produce the programmed output voltage. The voltage output of the operational amplifier is expressed in terms of the bit-controlled generator current outputs ($+I_G$) and the fixed offset current ($-I_{OS}$) in the following expression:

$$V_{OUT} = -1\ (-I_{OS} + I_G)\ Rfb$$

Examples of the DAC operation for sample programmed values are given in the following paragraphs.

4-13 Maximum Positive Value. The maximum positive output voltage, +10.235V, is produced by programming binary number 011111111111. After being transferred to, and stored in the second-level registers, the binary number is applied to the DAC. The MSB is inverted by its second-level flip-flop. resulting in all logical "1"'s (LO's) being applied to the DAC. With this input, all bit-controlled generators are turned off leaving only the offset generator to supply current to the operational amplifier. This current has a relative weight of I (1MSB-1LSB), or I (1023.5), and when passed through the operational amplifier feedback resistor produces an output of +10.235V.

4-14 Minimum Positive Value. The minimum programmable positive value is 0 volts; in binary form, 000000000000. Only the MSB is inverted on the 69321B. This input turns "on" all current generators except the MSB (SIGN BIT) generator. The resulting current from all the "on" generators is thus +I (1MSB-1LSB). The generator current and offset current are now equal, but of opposite sign, and thus cancel. With 0 output current, the output voltage becomes 0 volts.

4-15 Maximum Negative Value. To specify the maximum negative value, binary 100000000000 (-2048_{10}) must be programmed.

4-16 The above logic-level inputs to the DAC turn on all generators, resulting in a net $+I_G$ of +I (20475). Summing $+I_G$ with $-I_{OS}$ yields an output current of +I (1024.0) which the operational amplifier converts to -10.240V.

4-17 Minimum Negative Value. To program the minimum negative output voltage (-5mV) the 2's complement of 000000000000, or 111111111111, must be programmed. The resulting input to the DAC turns off all bit-controlled generators except the MSB generator. The summation of the MSB current, +I(1024), with the offset current -I(1023.5) yields an output current to the operational amplifer of +I (0.5). This converts to an output voltage of -5mV.

4-18 DETAILED CIRCUIT ANALYSIS

4-19 Figure 7-1 is a schematic diagram of the 69321B 12-Bit D/A Voltage Converter Card. The two major circuit groups of the 69321B, digital and analog, are covered separately in the following paragraphs.

4-20 DIGITAL CIRCUITS

4-21 The digital circuits include address gate and data transfer logic; and first and second level data storage registers with associated isolation transformers. In the following discussion, the method by which programmed data is stored and transferred from the first level storage registers to the second level storage registers is described without regard to strobe and transfer pulse timing. The timing is covered last as part of the data transfer logic discussion (Paragraph 4-29). Also covered under digital circuits are the timing flag generator and system enable control circuits.

4-22 Addressing. An output card is selected to receive new data when its associated address bits (B12/$\overline{B12}$) through B15/$\overline{B15}$) and the unit select line (U--) are all HI. Although both the true and complemented forms of the address bits are represented on Figure 7-1 (e.g. B12 and $\overline{B12}$) only one of the two states is present on each of the four address gate lines when the card is installed in a multiprogrammer slot. For example, if the output card is installed in slot 405, then bits B12 (1), $\overline{B13}$ (2), B14 (4), and $\overline{B15}$ (8) will be present on the address lines; and all four lines will be HI when slot 405 is addressed. The U-- line is HI when the associated multiprogrammer unit is selected as part of a control word.

4-23 When the slot and unit in which the output card is housed are addressed, the four address bits and U-- go HI. Data bits $\overline{B00}$ through $\overline{B10}$ and sign bit $\overline{B11}$ are also present at this time but are not yet entered into storage. Approximately 4µsec after the programmed word appears, a data strobe signal (DST) is received by the output card. The 4µsec delay of DST allows the data lines to settle before the data is stored. When DST appears, it enables NAND gate Z4 which produces a negative-going output signal. Transistor Q9 inverts the negative signal (STROBE 1) and applies it to the first level data storage registers and the data transfer logic. The output of Z4 is also applied to the Address•DST flip-flop to set the flip-flop if this is the first time the card is addressed after power turn-on or after a power reduction has been cleared.

4-24 First Level Data Storage. The first level data storage register is made up of three four-bit storage flip-flops (Z1, Z2, and Z3). Stage F/F1 of Z3 is controlled by sign bit $\overline{\text{B11}}$ and the remaining stages are controlled by magnitude bits $\overline{\text{B1Ø}}$ through $\overline{\text{BØØ}}$.

4-25 The individual stages are D-type, positive-level triggered flip-flops. The logical state at the D-input of a flip-flop is transferred to the Q output when the clock terminal (CLK) is strobed by the positive-going STROBE 1 signal.

4-26 When a sign or magnitude bit is programmed to a binary "1" at the computer or multiprogrammer switch register, the corresponding $\overline{\text{B--}}$ input from the multiprogrammer backplane goes LO. The STROBE 1 signal from Q9 transfers this LO level from the D-input to the Q-output.

4-27 Isolation Transformers. The purpose of the isolation transformers is to isolate the analog output signal ground (▽I) from the multiprogrammer and computer mainframe ground (▽C). The stored output logic levels of the first level data storage flip-flops are applied to the twelve data bit isolation transformers. When the data transfer logic generates a TRANSFER pulse, one side of all the isolation transformer primaries is switched to ground (▽C) for the period of the TRANSFER pulse. Any transformer receiving a HI level from its associated first level flip-flop will now generate a positive pulse in its secondary. The secondary of those transformers not receiving a HI level will remain at a LO level.

4-28 Second Level Data Storage. The second level data storage registers (Z6 through Z11) receive and store the logic levels appearing at the isolation transformer secondaries when the registers receive a positive STROBE 2 pulse from the data transfer logic. The second level data storage registers are dual, positive-edge triggered, D-type flip-flops. The D-input to a flip-flop is transferred to the Q-output on the positive edge of the STROBE 2 pulse. The $\overline{\text{Q}}$-output, of course, is always the complement of the Q-output. The MSB (SIGN BIT) is taken from the $\overline{\text{Q}}$ side of its flip-flop (thus essentially inverting the D-input level) while the data bits are taken from the Q-side of their associated flip-flops.

4-29 Data Transfer. The transfer of programmed data from the first level data storage registers through the isolation transformers to the second level data storage registers depends on the programmed state of the $\overline{\text{DTE}}$ mode bit, and when it is programmed relative to the time the card is addressed and data-strobed. The timing diagram on Figure 7-1 illustrates the two ways in which $\overline{\text{DTE}}$ can be used to transfer the programmed data. (Paragraph 3-20 describes the significance of the two methods from a programming standpoint.)

4-30 Data transfer logic Z5, STROBE 2 pulse isolation transformer T13, and STROBE 2 pulse drivers Q11 and Q12 implement these operations. In the first method shown on the timing diagram, data is strobed into the first level data storage registers by STROBE 1, at time T_1. At time T_2, the DTE mode is programmed on ($\overline{\text{DTE}}$ goes LO). The input $\overline{\text{DTE}}$ signal to the card is first buffered by emitter follower Q2 and then inverted by gate Z5G1. The output of Z5G1 (DTE) is applied to both NAND gate Z5G2 and inverter Z5G3. The second input to Z5G2 (STROBE 1) is LO at this time, so its output remains HI. The HI-to-LO transition at the output of Z5G3 (signifying the start of the DTE mode) is differentiated by C4, R14, and R15 producing a negative pulse designated $\overline{\text{DTE}}_{ST}$. Z5G4 inverts and squares $\overline{\text{DTE}}_{ST}$ and applies the resulting positive pulse to transformer driver Q10. The positive pulse switches on Q10, driving one side of all the primaries of the isolation transformers to ground (▽C) for approximately 1μsec. This TRANSFER pulse passes the stored first-level data through the transformers to the second-level registers, and also starts the timing flag generator circuit.

4-31 The TRANSFER pulse is also applied to STROBE 2 isolation transformer T13 and appears at the secondary of T13 as a positive pulse. The positive pulse is inverted twice, by Q11 and Q12, producing the positive STROBE 2 pulse. The STROBE 2 pulse occurs at time T_3 (slightly later than the TRANSFER pulse) and strobes the data appearing at the secondaries of the isolation transformers into the second level data storage registers.

4-32 In the second method shown on the timing diagram of Figure 7-1, DTE has been previously programmed on T_1'). At time T_2', the card is addressed and data strobed. NAND gate Z5G2 is enabled by STROBE 1 and DTE being HI simultaneously, and its output goes LO for the period of STROBE 1. The negative-going edge of this signal is differentiated by C5, R16, and R17. NAND gate Z5G4 inverts the negative input and applies the resulting positive pulse to transistor Q10. The remainder of the data transfer operation is identical to that described for the previous method.

4-33 Timing Flag Generator. The timing flag circuit produces a negative $\overline{\text{CTF}}$ pulse that starts when the TRANSFER pulse is generated, and lasts for approximately 30μsec. The purpose of $\overline{\text{CTF}}$ is to prevent the multiprogrammer from inputting new data to the output card while it is still processing and converting its last data input.

4-34 Before the negative-going transfer pulse is generated, transistor Q3 is biased on by the HI collector voltage of Q10, and Q4 is biased off. Capacitor C2 is charged positively to approximately

4 volts and transistor Q7 is biased on by the positive emitter voltage of Q6. The LO collector voltage of Q7 cuts off Q8, holding $\overline{CTF}$ at a HI level. The collector load resistor for Q8 is located on the logic and timing card of the multiprogrammer unit. (Transistor Q5 is normally "out" of the circuit by virtue of the base-emitter jumper connection. The jumper may be removed to change the $\overline{CTF}$ period, in which case Q5 functions as a capacitance multiplier. Note 4 on Figure 7-1 covers the procedure for changing the period of $\overline{CTF}$ from the standard 30μsec.)

4-35 When the TRANSFER pulse is generated, Q3 switches off and Q4 switches on. Capacitor C2 now discharges rapidly (in approximately 0.5μsec) through R6 and Q4. At the end of the TRANSFER pulse period, transistor Q4 is again switched off. Capacitor C2 now starts charging toward +5 volts through R5. During the period that C2 is recharging, Q7 is biased off and Q8 is biased on. The $\overline{CTF}$ line thus goes LO (busy). After approximately 30μsec, C2 will recharge to a voltage sufficiently high (approximatley +3.2 volts) to overcome the base-emitter diode drops of Q6 and Q7 and the drop across three junction diode CR25. At this time Q7 turns on, Q8 turns off, and $\overline{CTF}$ is reset to the HI (ready) state.

4-36 SYE Control Circuit. The SYE control circuit includes the +5V level sensing circuit, the card address•DST storage circuit, relay driver Q1 and normally open relay K1. These circuits control the output of the card, disabling it when power is first applied to the multiprogrammer, or if a power reduction occurs, or if SYE and the card address (and DST) are not both programmed.

4-37 The +5V level sensing circuit (Q15 and Q16 and associated components) initializes the output to the disabled state when power is turned on at the multiprogrammer and, in addition, disables the output if the +5V falls below approximately +4V. This feature is provided to prevent an erroneous output which might occur due to the unpredictable operation of the TTL storage circuits when operated from a supply that is below +4V. Instead, the sensing circuit disables the output card completely.

4-38 When power is turned on, +5V is applied across diodes CR29-CR31 and the base-emitter junction of transistor Q15. Q15 is, therefore, forward-biased and holds Q16 off. The +5V supply is also applied across R39 and C15. The capacitor cannot charge instantaneously, however, so that the pin 13 input to the address•DST storage flip-flop is held LO to reset the flip-flop. The pin 2 input to NAND gate G5, therefore, is LO and its output is HI. The HI output of G5 is inverted by G6 with the resulting LO input to relay driver Q1 reverse-biasing the transistor. With Q1 off, relay K1 is deenergized and the card output is disabled. After capacitor C15 charges to +3.8V (approximately 50msec), the input to the flip-flop is HI.

4-39 The output of the +5V level sensing circuit remains HI until the +5V falls below approximately +4V which is the point at which Q15 is turned off (the voltage applied across CR29-CR31 does not equal the combined drops of these diodes). When Q15 turns off, Q16 is biased on and capacitor C15 rapidly discharges through Q16 to reset the flip-flop (if it were set) and deenergize K1 to disable the output as described above.

4-40 Assuming that the +5V does not fall below +4V after turn on, the pin 13 input of the flip-flop is HI and the flip-flop is controlled by the address gate input at pin 9. When the card is addressed and data strobed, the pin 9 input is LO (for the period of DST) and the flip-flop is set. Thus, the pin 2 input of NAND gate G5 is HI. If SYE has been or is subsequently programmed on, the pin 1 input to G5 is also HI and its output is LO. The LO output is inverted by G6 with its HI output forward-biasing relay driver Q1. Q1 now conducts and energizes K1 to enable the output of the card. Thus, the output of the card is connected to the load as long as SYE is on and the card has been addressed and strobed at least once since power was turned on (or since the last power reduction). Of course, if SYE is programmed off, the pin 1 input to G5 is LO and the relay driver turned off by the LO input from G6. Thus, relay K1 is deenergized. Similarly, if power is turned off or the +5V falls below +4V, the relay is deenergized so that after power is restored, the card must be again addressed and strobed and SYE programmed on before its output is enabled.

4-41 ANALOG CIRCUITS

4-42 The analog circuits of the 69321B include the D/A converter (DAC module and operational amplifier), and +5 volts isolated supply. Both circuits are described in the following paragraphs.

4-43 D/A Converter. Operation of both the DAC module and the operational amplifier is described in detail in Paragraphs 4-9 through 4-17. The only components not covered previously are C14, R29, and R30 of the operational amplifier. Capacitor C14 serves as a frequency compensation and antioscillation element; R29 provides noise suppression; and R30 satisfies the requirement that both input terminals of the operational amplifier be at the same impedance.

4-44 Isolated +5V Supply. The isolated +5V supply provides isolated operating power for second-level data storage registers Z6 through Z11, and STROBE 2 pulse drivers Q11 and Q12. The supply consists of voltage divider R24-R25 and cascaded emitter follower Q14-Q13. The resistive divider provides the voltage reference and the emitter follower generates the necessary power gain.

SECTION V
MAINTENANCE

5-1 INTRODUCTION

5-2 This section contains preventive maintenance instructions, checkout procedures, troubleshooting procedures and calibration instructions for the 12-Bit D/A Voltage Converter Card, Model 69321B.

5-3 TEST EQUIPMENT REQUIRED

5-4 The Multiprogrammer master unit provides the signal inputs necessary for testing the 69321B. It is assumed that the master unit, as well as all other test instruments, are functioning properly at the outset of testing. The general purpose test instruments required for maintenance of the card are listed in Table 5-1.

Table 5-1. Test Equipment Required

TYPE	CHARACTERISTICS	USE	RECOMMENDED MODEL
Oscilloscope	Bandwidth: dc to 50MHz Sensitivity: 20mV/div.	Monitor timing flag generator waveforms.	HP Model 180A with 1804A and 1821A plug-ins.
Digital Multi-Function Meter	Voltage Accuracy: ±0.003% of reading.	Precision voltage and resistance measurements.	HP Model 3450A with Option 002.
Logic Probe	Impedance: 10 kilohms. Trig. Threshold: + 1.4V nominal. Min. Pulse Width: 30nsec.	Logic circuit trouble-shooting.	HP 10525A.

5-5 PREVENTIVE MAINTENANCE

5-6 The only preventive maintenance necessary is to keep the printed-circuit connector contact fingers clean. A nonabrasive eraser, such as a "Pink Pearl" or plastic eraser, should be lightly rubbed over the contact fingers to remove any film or foreign material.

5-7 CHECKOUT PROCEDURES

5-8 These procedures can be used to check operation of the 69321B when it is initially received, and as an aid in isolating trouble to a general circuit area if a malfunction is noted during operation. The procedures are performed with the output card plugged into an extender card and the extender card plugged into a multiprogrammer unit. A 69351A voltage regulator must also be installed in slot 600. It is suggested that the procedures for manually programming the 6936A or 6940A be reviewed, as necessary, before proceeding.

5-9 If the card fails a test, make certain that it was programmed correctly before starting troubleshooting. Also check that the multiprogrammer SYE interlock jumper (pins 18 and 19 of the data input connector) is in place before testing. An open SYE interlock jumper will prevent the SYE relay from being energized.

CAUTION

If there are any voltage programming connections between an output card and an external device, be sure to open the programming connections before performing the checkout procedure.

5-10 The physical and electrical locations of parts referred to in the following procedures are illustrated in Figure 7-1.

5-11 PROCEDURES

5-12 Perform the procedures in Table 5-2 to verify operation of the 69321B.

Table 5-2. Basic Checkout/Troubleshooting Procedure

TEST	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
1 SYE OFF	With no load connected across TB1-A and -B, measure the resistance across relay contacts of K1.	Open circuit.	Check SYE control circuit NORMAL INDICATIONS Q1-C = +12V K1 = deenergized Z14-6 = LO logic level Z14-3 = HI logic level
2 SYE ON	Same as Test 1. a. Program SYE mode as follows: (1) Select control word (bits 15-12 on). (2) Select SYE (bit 5 on) (3) Select unit address (for later use) (4) Touch LOAD OUTPUT b. Program the card address and output to zero. (1) Address the card slot. (2) Program data bits ØØ-11 off (binary Ø) (3) Touch LOAD OUTPUT	a. Open circuit. b. Closed circuit (K1 energizes)	a. Check SYE control circuit NORMAL INDICATIONS Z14-8 = LO Z4-8 = HI when LOAD OUTPUT touched b. Check SYE control circuit NORMAL INDICATIONS SYE input (P1-1 = HI Q1-C = approximately 0V K1 = energized Z14-6 = HI Z14-3 = LO Z14-8 = HI ⎫ Z4-8 = LO ⎬ (when LOAD OUTPUT touched) Z14-11 = HI ⎭ Z14-13 = HI Q15-C = 0V
3 DTE OFF	Connect a 3kΩ ±.05% load across TB1-A and -B and with a DVM measure voltage across the load resistor. Program a typical output as follows: (1) Address card slot. (2) Program +5.12V (bit 10 on, all other data bits off). (3) Touch LOAD OUTPUT	Output voltage reads 0V ±5.0mV	If the output voltage is greater than 0V ±5.0mV, the DTE circuit is faulty. Refer to Table 5-3 for troubleshooting procedures.
4 DTE ON	Program DTE on as follows: (1) Select control word. (2) Select DTE (bit 6 on) and SYE (bit 5 on). (3) Touch LOAD OUTPUT	+5.12V ±5.0mV	a. If the output voltage does not increase, check programming and repeat this test. If the output still does not change, refer to the data transfer circuits troubleshooting procedure (Table 5-3). b. If the output voltage changes but is out of tolerance, go on to next test.

Table 5-2. Basic Checkout/Troubleshooting Procedure (continued)

TEST	INSTUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
5 PROGRAMMING ACCURACY	Programming accuracy is checked at four critical values (0V, -5mV, +10.235V, and -10.240V) as follows: a. Program 0V: (1)Touch CLEAR REGISTER (2)Select slot address (3)Program 0V (all data bits off) (4)Touch LOAD OUTPUT b. Program -5mV: (1)Retain slot address (2)Program -5mV (all data bits on) (3)Touch LOAD OUTPUT c. Program +10.235V (1)Retain slot address (2)Program +10.235V (bit 11 off, all other data bits on) (3)Touch LOAD OUTPUT d. Program -10.240V: (1)Retain slot address (2)Program -10.240V (bit 11 on, all other data bits off) (3)Touch LOAD OUTPUT	a. 0V ±5.0mV b. -5mV ±5.0mV c. +10.235V ±5.0mV d. -10.240V ±5.0mV	INCORRECT READINGS If the output voltage readings are off, first try to calibrate the analog circuits (see paragraphs 5-25 and 5-26). If the output cannot be calibrated, troubleshoot the data storage circuits first (Table 5-4). If the data storage circuits are functioning properly, troubleshoot the analog circuits (Table 5-5).
6 BIT INTERACTION	Touch CLEAR REGISTER. Address the card slot. Select + sign (bit 11 off). Program each data bit from 0 through 10, in sequence. After the level corresponding to a programmed bit is observed, clear the bit back to 0 before going to the next bit. (Only one bit at a time should be in effect.) Note the level corresponding to each bit.	Bit 0: +5mV ±5.0mV Bit 1: +10mV ±5.0mV Bit 2: +20mV ±5.0mV Bit 3: +40mV ±5.0mV Bit 4: +80mV ±5.0mV Bit 5: +0.16V ±5.0mV Bit 6: +0.32V ±5.0mV Bit 7: +0.64V ±5.0mV Bit 8: +1.28V ±5.0mV Bit 9: +2.56V ±5.0mV Bit 10: +5.12V ±5.0mV	If any of the bits interact, first try to calibrate the analog circuits (see paragraphs 5-25 or 5-26). If the output cannot be calibrated, first troubleshoot the data storage circuits (Table 5-4). If the data storage circuits are functioning properly, troubleshoot the analog circuits (Table 5-5).
7 $\overline{\text{CTF}}$ TIMING	Using an oscilloscope, monitor the $\overline{\text{CTF}}$ pulse from test point (23) to 5V COM (1). Address the card slot. Touch LOAD OUTPUT.	Negative-going 30μsec (approx.) pulse.	If the test fails, refer to flag generator troubleshooting (Table 5-6).

5-13 TROUBLESHOOTING

5-14 The following paragraphs contain troubleshooting procedures covering four functional circuit areas of the 12-bit D/A voltage converter card. The circuit areas are:

(1) Data Transfer Circuits (address gate, data transfer, and strobe logic).

(2) Data Storage Circuits (first and second level storage registers and isolation transformers).

(3) Analog Circuits (DAC module, operational amplifier, and isolated + 5V power supply).

(4) Timing Flag Generator.

5-15 DATA TRANSFER CIRCUITS TROUBLESHOOTING

5-16 If programmed data is not stored when the DTE mode is programmed and the card is properly addressed and data strobed, it is likely that one of the components involved in generating the STROBE 1, TRANSFER, or STROBE 2 pulses is defective. Troubleshooting procedures for these circuits are given in Table 5-3.

Table 5-3. Data Transfer Circuits Troubleshooting

TEST	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
1 ADDRESS GATE AND STROBE 1 AMP.	At multiprogrammer switch register, program the following: (1)Control word (2)Unit address (3)LOAD OUTPUT (4)CLEAR REGISTER (5)Slot address Monitor STROBE 1 logic level at test point ⑥. Touch LOAD OUTPUT	HI logic level while LOAD OUTPUT is touched.	Check STROBE 1 amplifier circuit (Q9) and address gate Z4.
2 DTE BUFFER AND INVERTER	Program DTE on as follows: (1)Control word (2)Unit address (3)DTE mode (bit 6) on (4)LOAD OUTPUT Monitor logic levels at the following points: Test point ③ (Q2-B) Test point ④ (Q2-E) Z5-11 (DTE)	LO logic level LO logic level HI logic level	Check Q2 and Z5
3A DATA TRANSFER LOGIC	Program the following: (1)CLEAR REGISTER (2)Slot address While touching LOAD OUTPUT, monitor logic signals at the following points: Z5-3 ⑦ Z5-4 Test point ⑪ (Q10-C)	LO while LOAD OUTPUT is touched. Flashes LO when LOAD OUTPUT is touched. Flashes LO when LOAD OUTPUT is touched.	Check Z5 Check R16, R17 and C5 Check Z5, Q10, and R20

Table 5-3. Data Transfer Circuits Troubleshooting (continued)

TEST	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
3B DATA TRANSFER LOGIC	Program the following: (1) CLEAR REGISTER (2) Control word (3) DTE mode off (4) LOAD OUTPUT (5) Unit address (6) DTE mode on While touching LOAD OUTPUT, monitor logic signal at the following point: Test point (11) (Q10-C)	Flashes LO when LOAD OUTPUT is touched the first time.	Check Z5, R14, R15, and C4.
4 STROBE 2 ISO. AND AMPLIFIERS	Program the following: (1) CLEAR REGISTER (2) Slot address Tap LOAD OUTPUT while monitoring logic signals at the following test points: Test Point (17) (T13-sec)	Flashes HI each time LOAD OUTPUT is touched.	Check T13, and CR28, and C6
	Test Point (12) (Q11-C)	Flashes LO each time LOAD OUTPUT is touched.	Check Q11 and associated components.
	Test Point (13) (Q12-C)	Flashes HI each time LOAD OUTPUT is touched.	Check Q12 and associated components.

5-17 DATA STORAGE CIRCUITS

5-18 If any one of the three circuit elements (first and second level storage registers, and isolation transformers) associated with the storage of a programmed bit fails, the analog output of the card will be erroneous. Troubleshooting procedures for the data storage circuits are provided in Table 5-4.

Table 5-4. Data Storage Circuits Troubleshooting

TEST	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
DATA TRANSFER AND STORAGE	At the switch register, program each bit (11 through 0) on and then off, one bit at a time. As each bit is programmed, monitor the logic level at the input and output of both the first and second storage register stage associated with the programmed bit. Program each bit on and off as follows: (1) CLEAR REGISTER (2) Control word (3) Unit address (4) DTE mode (bit 6 on) (5) LOAD OUTPUT (6) CLEAR REGISTER (7) Slot address and select one data bit (start with bit Ø). (8) Touch LOAD OUTPUT. Check logic level at the input and output of the applicable storage register stages. (9) Clear the bit back to Ø. (10) Touch LOAD OUTPUT. Repeat logic level measurements. (11) Repeat above procedures for each bit.	<u>DATA BITS (0 through 10)</u> <u>For Bit ON</u>: D-input and Q-output of both stages are LO. <u>For Bit OFF</u>: D-input to stage 1 and Q-output of both stages are HI. D-input to stage 2 flashes HI when LOAD OUTPUT is touched. <u>SIGN BIT (11)</u> <u>For Bit ON</u>: D-input to both stages and Q-output of stage 1 are LO. $\overline{Q}$-output of stage 2 is HI. <u>For Bit OFF</u>: D-input and Q-output of stage 1 are HI. D-input to stage 2 flashes HI when LOAD OUTPUT is touched. $\overline{Q}$-output of stage 2 is LO.	Replace any stage having a normal input but an abnormal output.

5-19 ANALOG CIRCUITS TROUBLESHOOTING

5-20 Component failures in the analog circuits are difficult to isolate because of the feedback employed in the digital-to-analog converter circuits. A component failure anywhere in the loop can cause abnormal readings throughout the loop making diagnosis difficult. However, if the exact symptoms of the failure are determined, it is possible to rapidly troubleshoot these circuit and isolate the problem. Thus, the troubleshooting procedures for the DAC and operational amplifier circuits given in Table 5-5 are organized according to trouble symptoms which should be determined before performing the troubleshooting procedures. Table 5-5 also includes procedures for determining if the + 15V isolated power supply voltages are correct.

Table 5-5. Analog Circuits Troubleshooting

TEST	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
1 ±15V OPERATING POWER	Using DVM, check for ±15V operating power at the following points: PI-X Test Point (24) Test Point (27) PI-W Test Point (25) Test Point (28) Test Point (15) PI-V Test Point (26) Test Point (29) Test Point (16)	 Isolated ground (▽I) -15V + 15V	If normal voltages are present at the input connector but absent at all other points, check that jumpers W1, W2, and W3 are installed on the 69370A. If a voltage is absent at the input connector, check Voltage Regulator Card 69351A installed in slot 600.
2 DAC/ OPER. AMPL. ISOLATION PROCEDURE	(1) No output voltage is produced for any programmed value. Program maximum negative voltage and check DAC output voltage (with respect to ▽I) at junction of R26 and R29. (2) Unable to attain correct programmed output voltage. Program maximum positive voltage and note output reading. Next, program maximum negative voltage. (3) Programmed output voltage is incorrect by a constant amount.	If voltage $<$ 10mV check op. ampl. and feedback loop as follows: Check voltage at Z12-6. 1a. If output 0V±10mV. replace Z12. 1b. If output -3V to -14V, check R26-R29. 2a. If output voltage does not change, check the DAC (verify power and digital input correct before replacing). 2b. If output voltage changes, check the feedback loop as described in 1 above. Check for bit interaction in the digital circuits (Table 5-2, step 6). If the digital circuits are correct, replace DAC.	If voltage 0±10mV, replace the DAC but only after verifying that supply voltages are normal, the digital input to the DAC is normal, and programming has been executed correctly.

5-21 TIMING FLAG GENERATOR TROUBLESHOOTING

5-22 The timing flag generator circuit should generate a negative 30μsec $\overline{CTF}$ pulse whenever data is transferred to the second level storage registers. This occurs when the card is addressed and strobed and the DTE mode has been programmed on. Troubleshooting procedures for the timing flag generator circuit are given in Table 5-6.

Table 5-6. Timing Flag Generator Troubleshooting

TEST	INSTRUCTIONS	NORMAL INDICATION	IF INDICATION IS ABNORMAL
$\overline{CTF}$ CIRCUIT	At the switch register, program the following: (1)CLEAR REGISTER (2)Control word (3)Unit select (4)DTE mode on (5)LOAD OUTPUT (6)CLEAR REGISTER (7)Slot address Tap LOAD OUTPUT while observing waveforms at the following test points:		
	Test Point (19)	Waveform (19), Figure 7-1.	Check C1 and R3
	Test Point (20)	Waveform (20), Figure 7-1.	Check Q3 and R4
	Test Point (21)	Waveform (21), Figure 7-1.	Check Q4, R5, R6 and C2
	Test Point (22)	Waveform (22), Figure 7-1.	Check Q6, Q7, R7, R8, R9 and CR25
	Test Point (23)	Waveform (23), Figure 7-1.	Check Q8

5-23 CALIBRATION

5-24 The 69321B is designed to operate with either of two different model DAC's. The model in use on any given card can be determined by noting the HP part number stamped on the module. While the two DAC's perform identical functions, they differ internally and consequently require different calibration procedures. Paragraphs 5-25 and 5-26 cover the two different procedures.

NOTE

All calibration procedures must be performed with the 69321B card plugged into an extender card and the extender card plugged into a 400-series multiprogrammer slot. A 69351A voltage regulator must also be installed in slot 600. The physical locations of the calibration controls described in these procedures are illustrated on the component location diagram of Figure 7-1.

5-25 Model (Datel) Calibration Procedures

a. Connect a 3K ohm load resistor across output terminals TB1-A (SIG) and B (COM).

b. Energize the multiprogrammer system.

c. Connect DVM across the output terminals.

d. Allow a 20-minute warm-up period before proceeding.

e. At the multiprogrammer switch register, program the required unit address and control modes as follows:

(1) Touch CLEAR REGISTER
(2) Select control word (bits 15 through 12 on)
(3) Select unit address (bits 3 through 0 to unit address)
(4) Select SYE (bit 5 on)
(5) Select DTE (bit 6 on)
(6) Touch LOAD OUTPUT

f. Program 0V and transmit to 69321B card as follows:

(1) Touch CLEAR REGISTER
(2) Select slot address (bits 15 through 12 to slot address)
(3) Program 0V (bits 11 through 0 off)
(4) Touch LOAD OUTPUT

g. Adjust potentiometer R36 for 0V ± 1mV indication on the DVM.

h. Program + 10.235V as follows:

(1) Retain slot address
(2) Select + 10.235V (bit 11 off; bits 10 through 0 on)
(3) Touch LOAD OUTPUT

i. Adjust potentiometer R28 for + 10.235V ± 1mV indication on the DVM.

j. Repeat the checkout procedure. Table 5-2, to verify programming accuracy.

5-26 Model (Hybrid) Calibration Procedures

a. Connect a 3K ohm load resistor across output terminals TB1-A (SIG) and B (COM).

b. Energize the multiprogrammer system.

c. Connect DVM across the output terminals.

d. Allow a 20-minute warm-up period before proceeding.

e. At the multiprogrammer switch register, program the required unit address and control modes as follows:

(1) Touch CLEAR REGISTER
(2) Select control word (bits 15 through 12 on)
(3) Select unit address (bits 3 through 0 to unit address)
(4) Select SYE (bit 5 on)
(5) Select DTE (bit 6 on)
(6) Touch LOAD OUTPUT

f. Program +5.12V as follows:

(1) Select slot address (bits 15 through 12)
(2) Program +5.12V (bit 11 off, bit 10 on, bits 9 through ØØ off).
(3) Touch LOAD OUTPUT.
(4) Record reading on DVM.

g. Program +5.115V as follows:

(1) Select slot address (bits 15 through 12)
(2) Program +5.115V (bits 11 and 10 off, bits 9 through ØØ on).
(3) Touch LOAD OUTPUT.
(4) Adjust potentiometer R34 so that DVM reads 5±1mV less than reading recorded in step f (4).

h. Program 0V as follows:

(1) Select slot address (bits 15 through 12)
(2) Program 0V (bits 11 through ØØ off).
(3) Touch LOAD OUTPUT.
(4) Record reading on DVM.

i. Program -5mV as follows:

(1) Select slot address (bits 15 through 12)
(2) Program -5mV (bits 11 through ØØ on)
(3) Touch LOAD OUTPUT
(4) Adjust potentiometer R32 so that DVM reads 5 ± 1mV less than reading recorded in step h (4).

j. Repeat step h, adjust potentiometer R35 so that DVM reads 0 ± 1mV.

k. Program +10.235V as follows:

(1) Select slot address (bits 15 through 12).
(2) Program +10.235V (bit 11 off, bits 10 through ØØ on).
(3) Touch LOAD OUTPUT
(4) Adjust potentiometer R28 so that DVM reads +10.235V ± 1mV.

l. Repeat the checkout procedure, Table 5-2 to verify programming accuracy.

SECTION VI
REPLACEABLE PARTS

6-1 INTRODUCTION

6-2 This section contains information for ordering replacement parts. Table 6-4 lists parts in alphanumeric order by reference designators and provides the following information:

a. Reference Designators. Refer to Table 6-1.

b. Description. Refer to Table 6-2 for abbreviations.

c. Total Quantity (TQ). Given only the first time the part number is listed except in instruments containing many sub-modular assemblies, in which case the TQ appears the first time the part number is listed in each assembly.

d. Manufacturer's Part Number or Type.

e. Manufacturer's Federal Supply Code Number. Refer to Table 6-3 for manufacturer's name and address.

f. Hewlett-Packard Part Number.

g. Recommended Spare Parts Quantity (RS) for complete maintenance of one instrument during one year of isolated service.

h. Parts not identified by a reference designator are listed at the end of Table 6-4 under Mechanical and/or Miscellaneous. The former consists of parts belonging to and grouped by individual assemblies; the latter consists of all parts not immediately associated with an assembly.

6-3 ORDERING INFORMATION

6-4 To order a replacement part, address order or inquiry to your local Hewlett-Packard sales office (see lists at rear of this manual for addresses). Specify the following information for each part: Model, complete serial number, and any Option or special modification (J) numbers of the instrument; Hewlett-Packard part number; circuit reference designator; and description. To order a part not listed in Table 6-4, give a complete description of the part, its function, and its location.

Table 6-1. Reference Designators

A	= assembly	E	= miscellaneous electronic part
B	= blower (fan)	F	= fuse
C	= capacitor	J	= jack, jumper
CB	= circuit breaker	K	= relay
CR	= diode	L	= inductor
DS	= device, signaling (lamp)	M	= meter

Table 6-1. Reference Designators (Continued)

P	= plug	V	= vacuum tube, neon bulb, photocell, etc.
Q	= transistor	VR	= zener diode
R	= resistor	X	= socket
S	= switch	Z	= integrated circuit or network
T	= transformer		
TB	= terminal block		
TS	= thermal switch		

Table 6-2. Description Abbreviations

A	= ampere	mfr	= manufacturer
ac	= alternating current	mod.	= modular or modified
assy.	= assembly	mtg	= mounting
bd	= board	n	= nano = 10^{-9}
bkt	= bracket	NC	= normally closed
°C	= degree Centigrade	NO	= normally open
cd	= card	NP	= nickel-plated
coef	= coefficient	Ω	= ohm
comp	= composition	obd	= order by description
CRT	= cathode-ray tube	OD	= outside diameter
CT	= center-tapped	p	= pico = 10^{-12}
dc	= direct current	P.C.	= printed circuit
DPDT	= double pole, double throw	pot.	= potentiometer
DPST	= double pole, single throw	p-p	= peak-to-peak
elect	= electrolytic	ppm	= parts per million
encap	= encapsulated	pvr	= peak reverse voltage
F	= farad	rect	= rectifier
°F	= degree Farenheit	rms	= root mean square
fxd	= fixed	Si	= silicon
Ge	= germanium	SPDT	= single pole, double throw
H	= Henry	SPST	= single pole, single throw
Hz	= Hertz	SS	= small signal
IC	= integrated circuit	T	= slow-blow
ID	= inside diameter	tan.	= tantulum
incnd	= incandescent	Ti	= titanium
k	= kilo = 10^3	V	= volt
m	= milli = 10^{-3}	var	= variable
M	= mega = 10^6	ww	= wirewound
μ	= micro = 10^{-6}	W	= Watt
met.	= metal		

Table 6-3. Code List of Manufacturers

CODE NO.	MANUFACTURER	ADDRESS
00629	EBY Sales Co., Inc.	Jamaica, N.Y.
00656	Aerovox Corp.	New Bedford, Mass.
00853	Sangamo Electric Co. S. Carolina Div.	Pickens, S.C.
01121	Allen Bradley Co.	Milwaukee, Wis.
01255	Litton Industries, Inc.	Beverly Hills, Calif.
01281	TRW Semiconductors, Inc.	Lawndale, Calif.
01295	Texas Instruments, Inc. Semiconductor-Components Div.	Dallas, Texas
01686	RCL Electronics, Inc.	Manchester, N.H.
01930	Amerock Corp.	Rockford, Ill.
02107	Sparta Mfg. Co.	Dover, Ohio
02114	Ferroxcube Corp.	Saugerties, N.Y.
02606	Fenwal Laboratories	Morton Grove, Ill.
02660	Amphenol Corp.	Broadview, Ill.
02735	Radio Corp. of America, Solid State and Receiving Tube Div.	Somerville, N.J.
03508	G.E. Semiconductor Products Dept.	Syracuse, N.Y.
03797	Eldema Corp.	Compton, Calif.
03877	Transitron Electronic Corp.	Wakefield, Mass.
03888	Pyrofilm Resistor Co. Inc.	Cedar Knolls, N.J.
04009	Arrow, Hart and Hegeman Electric Co.	Hartford, Conn.
04072	ADC Electronics, Inc.	Harbor City, Calif.
04213	Caddell & Burns Mfg. Co. Inc.	Mineola, N.Y.
04404	*Hewlett-Packard Co. Palo Alto Div.	Palo Alto, Calif.
04713	Motorola Semiconductor Prod. Inc.	Phoenix, Arizona
05277	Westinghouse Electric Corp. Semiconductor Dept.	Youngwood, Pa.
05347	Ultronix, Inc.	Grand Junction, Colo.
05820	Wakefield Engr. Inc.	Wakefield, Mass.
06001	General Elect. Co. Electronic Capacitor & Battery Dept.	Irmo, S.C.
06004	Bassik Div. Stewart-Warner Corp.	Bridgeport, Conn.
06486	IRC Div. of TRW Inc. Semiconductor Plant	Lynn, Mass.
06540	Amatom Electronic Hardware Co. Inc.	New Rochelle, N.Y.
06555	Beede Electrical Instrument Co.	Penacook, N.H.
06666	General Devices Co. Inc.	Indianapolis, Ind.
06751	Semcor Div. Components, Inc.	Phoenix, Arizona
06776	Robinson Nugent, Inc.	New Albany, Ind.
06812	Torrington Mfg. Co., West Div.	Van Nuys, Calif.
07137	Transistor Electronics Corp.	Minneapolis, Minn.

CODE NO.	MANUFACTURER	ADDRESS
07138	Westinghouse Electric Corp. Electronic Tube Div.	Elmira, N.Y.
07263	Fairchild Camera and Instrument Corp. Semiconductor Div.	Mountain View, Calif.
07387	Birtcher Corp., The	Los Angeles, Calif.
07397	Sylvania Electric Prod. Inc. Sylvania Electronic Systems Western Div.	Mountain View, Calif.
07716	IRC Div. of TRW Inc. Burlington Plant	Burlington, Iowa
07910	Continental Device Corp.	Hawthorne, Calif.
07933	Raytheon Co. Components Div. Semiconductor Operation	Mountain View, Calif.
08484	Breeze Corporations, Inc.	Union, N.J.
08530	Reliance Mica Corp.	Brooklyn, N.Y.
08717	Sloan Company, The	Sun Valley, Calif.
08730	Vemaline Products Co. Inc.	Wyckoff, N.J.
08806	General Elect. Co. Miniature Lamp Dept.	Cleveland, Ohio
08863	Nylomatic Corp.	Norrisville, Pa.
08919	RCH Supply Co.	Vernon, Calif.
09021	Airco Speer Electronic Components	Bradford, Pa.
09182	*Hewlett-Packard Co. New Jersey Div.	Rockaway, N.J.
09213	General Elect. Co. Semiconductor Prod. Dept.	Buffalo, N.Y.
09214	General Elect. Co. Semiconductor Prod. Dept.	Auburn, N.Y.
09353	C & K Components Inc.	Newton, Mass.
09922	Burndy Corp.	Norwalk, Conn.
11115	Wagner Electric Corp. Tung-Sol Div.	Bloomfield, N.J.
11236	CTS of Berne, Inc.	Berne, Ind.
11237	Chicago Telephone of Cal. Inc.	So. Pasadena, Calif.
11502	IRC Div. of TRW Inc. Boone Plant	Boone, N.C.
11711	General Instrument Corp Rectifier Div.	Newark, N.J.
12136	Philadelphia Handle Co. Inc.	Camden, N.J.
12615	U.S. Terminals, Inc.	Cincinnati, Ohio
12617	Hamlin Inc.	Lake Mills, Wisconsin
12697	Clarostat Mfg. Co. Inc.	Dover, N.H.
13103	Thermalloy Co.	Dallas, Texas
14493	*Hewlett-Packard Co. Loveland Div.	Loveland, Colo.
14655	Cornell-Dubilier Electronics Div. Federal Pacific Electric Co.	Newark, N.J.
14936	General Instrument Corp. Semiconductor Prod. Group	Hicksville, N.Y.
15801	Fenwal Elect.	Framingham, Mass.
16299	Corning Glass Works, Electronic Components Div.	Raleigh, N.C.

*Use Code 28480 assigned to Hewlett-Packard Co., Palo Alto, California

Table 6-3. Code List of Manufacturers (Continued)

CODE NO.	MANUFACTURER	ADDRESS
16758	Delco Radio Div. of General Motors Corp.	Kokomo, Ind.
17545	Atlantic Semiconductors, Inc.	Asbury Park, N.J.
17803	Fairchild Camera and Instrument Corp Semiconductor Div. Transducer Plant	Mountain View, Calif.
17870	Daven Div. Thomas A. Edison Industries McGraw-Edison Co.	Orange, N.J.
18324	Signetics Corp.	Sunnyvale, Calif.
19315	Bendix Corp. The Navigation and Control Div.	Teterboro, N.J.
19701	Electra/Midland Corp.	Mineral Wells, Texas
21520	Fansteel Metallurgical Corp.	No. Chicago, Ill.
22229	Union Carbide Corp. Electronics Div.	Mountain View, Calif.
22753	UID Electronics Corp.	Hollywood, Fla.
23936	Pamotor, Inc.	Pampa, Texas
24446	General Electric Co.	Schenectady, N.Y.
24455	General Electric Co. Lamp Div. of Consumer Prod. Group	Nela Park, Cleveland, Ohio
24655	General Radio Co.	West Concord, Mass.
24681	LTV Electrosystems Inc Memcor/Components Operations	Huntington, Ind.
26982	Dynacool Mfg. Co. Inc.	Saugerties, N.Y.
27014	National Semiconductor Corp.	Santa Clara, Calif.
28480	Hewlett-Packard Co.	Palo Alto, Calif.
28520	Heyman Mfg. Co.	Kenilworth, N.J.
28875	IMC Magnetics Corp. New Hampshire Div.	Rochester, N.H.
31514	SAE Advance Packaging, Inc.	Santa Ana, Calif.
31827	Budwig Mfg. Co.	Ramona, Calif.
33173	G. E. Co. Tube Dept.	Owensboro, Ky.
35434	Lectrohm, Inc.	Chicago, Ill.
37942	P. R. Mallory & Co. Inc.	Indianapolis, Ind.
42190	Muter Co.	Chicago, Ill.
43334	New Departure-Hyatt Bearings Div. General Motors Corp.	Sandusky, Ohio
44655	Ohmite Manufacturing Co.	Skokie, Ill.
46384	Penn Engr. and Mfg. Corp.	Doylestown, Pa.
47904	Polaroid Corp.	Cambridge, Mass.
49956	Raytheon Co.	Lexington, Mass.
55026	Simpson Electric Co. Div. of American Gage and Machine Co.	Chicago, Ill.
56289	Sprague Electric Co.	North Adams, Mass.
58474	Superior Electric Co.	Bristol, Conn.
58849	Syntron Div. of FMC Corp.	Homer City, Pa.
59730	Thomas and Betts Co.	Philadelphia, Pa.
61637	Union Carbide Corp.	New York, N.Y.
63743	Ward Leonard Electric Co.	Mt. Vernon, N.Y.

CODE NO.	MANUFACTURER	ADDRESS
70563	Amperite Co. Inc.	Union City, N.J.
70901	Beemer Engrg. Co.	Fort Washington, Pa.
70903	Belden Corp.	Chicago, Ill.
71218	Bud Radio, Inc.	Willoughby, Ohio
71279	Cambridge Thermionic Corp.	Cambridge, Mass.
71400	Bussmann Mfg. Div. of McGraw & Edison Co.	St. Louis, Mo.
71450	CTS Corp.	Elkhart, Ind.
71468	I. T. T. Cannon Electric Inc.	Los Angeles, Calif.
71590	Globe-Union Inc. Centralab Div.	Milwaukee, Wis.
71700	General Cable Corp. Cornish Wire Co. Div.	Williamstown, Mass.
71707	Coto Coil Co. Inc.	Providence, R. I.
71744	Chicago Miniature Lamp Works	Chicago, Ill.
71785	Cinch Mfg. Co. and Howard B. Jones Div.	Chicago, Ill.
71984	Dow Corning Corp.	Midland, Mich.
72136	Electro Motive Mfg. Co. Inc.	Willimantic, Conn.
72619	Dialight Corp.	Brooklyn, N.Y.
72699	General Instrument Corp.	Newark, N.J.
72765	Drake Mfg. Co.	Harwood Heights, Ill.
72962	Elastic Stop Nut Div. of Amerace Esna Corp.	Union, N.J.
72982	Erie Technological Products Inc.	Erie, Pa.
73096	Hart Mfg. Co.	Hartford, Conn.
73138	Beckman Instruments Inc. Helipot Div.	Fullerton, Calif.
73168	Fenwal, Inc.	Ashland, Mass.
73293	Hughes Aircraft Co. Electron Dynamics Div.	Torrance, Calif.
73445	Amperex Electronic Corp.	Hicksville, N.Y.
73506	Bradley Semiconductor Corp.	New Haven, Conn.
73559	Carling Electric, Inc.	Hartford, Conn.
73734	Federal Screw Products, Inc.	Chicago, Ill.
74193	Heinemann Electric Co.	Trenton, N.J.
74545	Hubbell Harvey Inc.	Bridgeport, Conn.
74868	Amphenol Corp. Amphenol RF Div.	Danbury, Conn.
74970	E. F. Johnson Co.	Waseca, Minn.
75042	IRC Div. of TRW, Inc.	Philadelphia, Pa.
75183	*Howard B. Jones Div. of Cinch Mfg. Corp.	New York, N.Y.
75376	Kurz and Kasch, Inc.	Dayton, Ohio
75382	Kilka Electric Corp.	Mt. Vernon, N.Y.
75915	Littlefuse, Inc.	Des Plaines, Ill.
76381	Minnesota Mining and Mfg. Co.	St. Paul, Minn.
76385	Minor Rubber Co. Inc.	Bloomfield, N.J.
76487	James Millen Mfg. Co. Inc.	Malden, Mass.
76493	J. W. Miller Co.	Compton, Calif.

*Use Code 71785 assigned to Cinch Mfg. Co., Chicago, Ill.

Table 6-3. Code List of Manufacturers (Continued)

CODE NO.	MANUFACTURER	ADDRESS
76530	Cinch	City of Industry, Calif.
76854	Oak Mfg. Co. Div. of Oak Electro/Netics Corp.	Crystal Lake, Ill.
77068	Bendix Corp., Electrodynamics Div.	No. Hollywood, Calif.
77122	Palnut Co.	Mountainside, N.J.
77147	Patton-MacGuyer Co.	Providence, R.I.
77221	Phaostron Instrument and Electronic Co.	South Pasadena, Calif.
77252	Philadelphia Steel and Wire Corp.	Philadelphia, Pa.
77342	American Machine and Foundry Co. Potter and Brumfield Div.	Princeton, Ind.
77630	TRW Electronic Components Div.	Camden, N.J.
77764	Resistance Products Co.	Harrisburg, Pa.
78189	Illinois Tool Works Inc. Shakeproof Div.	Elgin, Ill.
78452	Everlock Chicago, Inc.	Chicago, Ill.
78488	Stackpole Carbon Co.	St. Marys, Pa.
78526	Stanwyck Winding Div. San Fernando Electric Mfg. Co. Inc.	Newburgh, N.Y.
78553	Tinnerman Products, Inc.	Cleveland, Ohio
78584	Stewart Stamping Corp.	Yonkers, N.Y.
79136	Waldes Kohinoor, Inc.	L.I.C., N.Y.
79307	Whitehead Metals Inc.	New York, N.Y.
79727	Continental-Wirt Electronics Corp.	Philadelphia, Pa.
79963	Zierick Mfg. Co.	Mt. Kisco, N.Y.
80031	Mepco Div. of Sessions Clock Co.	Morristown, N.J.
80294	Bourns, Inc.	Riverside, Calif.
81042	Howard Industries Div. of Msl Ind. Inc.	Racine, Wisc.
81073	Grayhill, Inc.	La Grange, Ill.
81483	International Rectifier Corp.	El Segundo, Calif.
81751	Columbus Electronics Corp.	Yonkers, N.Y.
82099	Goodyear Sundries & Mechanical Co. Inc.	New York, N.Y.
82142	Airco Speer Electronic Components	Du Bois, Pa.
82219	Sylvania Electric Products Inc. Electronic Tube Div. Receiving Tube Operations	Emporium, Pa.
82389	Switchcraft, Inc.	Chicago, Ill.
82647	Metals and Controls Inc. Control Products Group	Attleboro, Mass.
82866	Research Products Corp.	Madison, Wis.
82877	Rotron Inc.	Woodstock, N.Y.
82893	Vector Electronic Co.	Glendale, Calif.
83058	Carr Fastener Co.	Cambridge, Mass.
83186	Victory Engineering Corp.	Springfield, N.J.
83298	Bendix Corp. Electric Power Div.	Eatontown, N.J.
83330	Herman H. Smith, Inc.	Brooklyn, N.Y.
83385	Central Screw Co.	Chicago, Ill.
83501	Gavitt Wire and Cable Div. of Amerace Esna Corp.	Brookfield, Mass.
83508	Grant Pulley and Hardware Co.	West Nyack, N.Y.
83594	Burroughs Corp. Electronic Components Div.	Plainfield, N.J.
83835	U.S. Radium Corp.	Morristown, N.J.
83877	Yardeny Laboratories, Inc.	New York, N.Y.
84171	Arco Electronics, Inc.	Great Neck, N.Y.
84411	TRW Capacitor Div.	Ogallala, Neb.
86684	RCA Corp. Electronic Components	Harrison, N.J.
86838	Rummel Fibre Co.	Newark, N.J.
87034	Marco & Oak Industries a Div. of Oak Electro/netics Corp.	Anaheim, Calif.
87216	Philco Corp. Lansdale Div.	Lansdale, Pa.
87585	Stockwell Rubber Co. Inc.	Philadelphia, Pa.
87929	Tower-Olschan Corp.	Bridgeport, Conn.
88140	Cutler-Hammer Inc. Power Distribution and Control Div. Lincoln Plant	Lincoln, Ill.
88245	Litton Precision Products Inc, USECO Div. Litton Industries	Van Nuys, Calif.
90634	Gulton Industries Inc.	Metuchen, N.J.
90763	United-Car Inc.	Chicago, Ill.
91345	Miller Dial and Nameplate Co.	El Monte, Calif.
91418	Radio Materials Co.	Chicago, Ill.
91506	Augat, Inc.	Attleboro, Mass.
91637	Dale Electronics, Inc.	Columbus, Neb.
91662	Elco Corp.	Willow Grove, Pa.
91929	Honeywell Inc. Div. Micro Switch	Freeport, Ill.
92825	Whitso, Inc.	Schiller Pk., Ill.
93332	Sylvania Electric Prod. Inc. Semi-conductor Prod. Div.	Woburn, Mass.
93410	Essex Wire Corp. Stemco Controls Div.	Mansfield, Ohio
94144	Raytheon Co. Components Div. Ind. Components Oper.	Quincy, Mass.
94154	Wagner Electric Corp. Tung-Sol Div.	Livingston, N.J.
94222	Southco Inc.	Lester, Pa.
95263	Leecraft Mfg. Co. Inc.	L.I.C., N.Y.
95354	Methode Mfg. Co.	Rolling Meadows, Ill.
95712	Bendix Corp. Microwave Devices Div.	Franklin, Ind.
95987	Weckesser Co. Inc.	Chicago, Ill.
96791	Amphenol Corp. Amphenol Controls Div.	Janesville, Wis.
97464	Industrial Retaining Ring Co.	Irvington, N.J.
97702	IMC Magnetics Corp. Eastern Div.	Westbury, N.Y.
98291	Sealectro Corp.	Mamaroneck, N.Y.
98410	ETC Inc.	Cleveland, Ohio
98978	International Electronic Research Corp.	Burbank, Calif.
99934	Renbrandt, Inc.	Boston, Mass.

Table 6-4. Replaceable Parts

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
A4 C1	fxd, mylar 0.001μF 200Vdc	7	192P10292	56289	0160-0153	2
C2	fxd, mylar 0.0022μF 200Vdc	1	292P33392	56289	0160-0154	1
C3-7	fxd, mylar 0.001μF 200Vdc	-	192P10292	56289	0160-0153	
C8-12	fxd, elect. 1.0μF 35Vdc	7	150D105X9035A2	56289	0180-0291	2
C13	fxd, mylar 0.001μF 200Vdc	-	192P10292	56289	0160-0153	
C14	fxd, mica 30pF 300Vdc	1		28480	0160-2199	1
C15-16	fxd, elect. 1.0μF 35Vdc	-	150D105X9035A2	56289	0180-0291	
CR1-24	Diode, Si. 250mW 200V	29		28480	1901-0033	10
CR25	Stabistor, Si. 10prv	2		28480	1901-0460	2
CR26-30	Diode, Si. 250mW 200V	-		28480	1901-0033	
CR31	Stabistor, Si. 10prv	-		28480	1901-0460	
K1	Relay, reed, 1form A 12Vdc 1.2Km	1		28480	0490-0399	1
Q1	SS NPN Si.	12		28480	1854-0071	7
Q2	SS NPN Si.	2		28480	1854-0202	2
Q3-5	SS NPN Si.	-		28480	1854-0071	
Q6	SS NPN Si.	-		28480	1854-0202	
Q7-9	SS NPN Si.	-		28480	1854-0071	
Q10	SS NPN Si.	3		28480	1854-0271	3
Q11-12	SS NPN Si.	-		28480	1854-0071	
Q13	SS NPN Si.	-		28480	1854-0271	
Q14-16	SS NPN Si.	3		28480	1854-0071	3
R1	fxd, comp 1.5KΩ ±5% 1/4W	2	CB1525	01121	0683-1525	1
R2	fxd, comp 3KΩ ±5% 1/4W	5	CB3025	01121	0683-3025	1
R3	fxd, comp 10KΩ ±5% 1/4W	3	CB1035	01121	0683-1035	1
R4	fxd, comp 1KΩ ±5% 1/4W	2	CB1025	01121	0683-1025	1
R5	fxd, comp 20KΩ ±5% 1/4W	2	CB2035	01121	0683-2035	1
R6	fxd, comp 200Ω ±5% 1/4W	2	CB2015	01121	0683-2015	1
R7	fxd, comp 680Ω ±5% 1/4W	1	CB6815	01121	0683-6815	1
R8	fxd, comp 200Ω ±5% 1/4W	-	CB2015	01121	0683-2015	
R9	fxd, comp 20KΩ ±5% 1/4W	-	CB2035	01121	0683-2035	
R10	fxd comp 2KΩ ±5% 1/4W	2	CB2025	01121	0683-2025	1
R11	fxd, comp 510Ω ±5% 1/4W	1	CB5115	01121	0683-5115	1
R12	fxd, comp 1.5KΩ ±5% 1/4W	-	CB1525	01121	0683-1525	
R13	fxd, comp 1KΩ ±5% 1/4W	1	CB1025	01121	0683-1025	1
R14-17	fxd, comp 3KΩ ±5% 1/4W	-	CB3025	01121	0683-3025	
R18	fxd, comp 120Ω ±5% 1/4W	1	CB1215	01121	0683-1215	1
R19	fxd, comp 300Ω ±5% 1/4W	1	CB3015	01121	0683-3015	1
R20	fxd, comp 100Ω ±5% 1/4W	1	CB1015	01121	0683-1015	1
R21-22	fxd, comp 4.7KΩ ±5% 1/4W	2	CB4725	01121	0683-4725	1
R23	fxd, comp 7.5KΩ ±5% 1/4W	1	CB7525	01121	0683-7525	1
R24	fxd, film 10.1KΩ ±1% 1/4W	1	Type CCA T-0	07716	0757-0141	1
R25	fxd, film 7.5KΩ ±1% 1/8W	1	Type CEA T-0	07716	0757-0440	1
R26	fxd, ww 10KΩ ±.1% 1/8W	1		28480	0811-2577	1
R27	fxd, film ±% 1/8W (Selected)	1		28480	0698	
R28	var, ww 100Ω ±5% 1W	1	CT-100-4	07716	2100-1450	1
R29-30	fxd, film 1KΩ ±1% 1/8W	2	Type CEA T-0	07716	0757-0280	1
R31	fxd, comp 110KΩ ±1% 1/8W	2			0757-0466	1
R32	var, ww 20KΩ ±5% 1W	3	CT-100-4	07716	2100-1777	1
R33	fxd, comp 110KΩ ±1% 1/8W	-			0757-0466	
R34-35	var, ww 20KΩ ±5% 1W	-	CT-100-4	07716	2100-1777	
R36	var, ww 300Ω ±5% 1W	1	CT-100-4	07716	2100-1611	1
R37	fxd, comp 2KΩ ±5% 1/4W	-	CB2025	01121	0683-2025	1

Table 6-4. Replaceable Parts (continued)

REF. DESIG.	DESCRIPTION	TQ	MFR. PART NO.	MFR. CODE	HP PART NO.	RS
R38	fxd, comp 5.1KΩ ±5% 1/4W	1	CB5125	01121	0683-5125	1
R39	fxd, comp 51KΩ ±5% 1/4W	1	CB5135	01121	0683-5135	1
T1-13	Transformer, signal	13		28480	69370-80091	3
Z1-3	Quad Bistable Latch, IC	3	SN74L75N	01295	1820-0876	3
Z4	8-input NAND Gate, IC	1	SN7430N	01295	1820-0070	1
Z5	Quad 2-input NAND Gate, IC	1	SN7400N	01295	1820-0054	1
Z6-11	Dual D-type flip-flop, IC	6		01295	1820-0596	6
Z12	Operational Amplifier, IC	1	SL6471	27014	1820-0104	1
Z13A*	DAC Module, IC	1		28480	1813-0012	1
Z13B*	DAC Module, IC	1		28480	1813-0027	1
Z14	Quad 2-input NAND Gate, IC	1	SN12955	27014	1820-0583	1
	MECHANICAL					
	IC Socket, 16-pin (Z1-3)	3	316-AG5D-3R	91506	1200-0767	1
	IC Socket, 14-pin (Z4-14)	10	314-AG5D-3R	91506	1200-0768	2
	Terminal Block, TB1	1		28480	0360-1602	1
	Extractor Handle, Marked	1		28480	5081-4915	
	Box, Corrugated	1		28480	9211-0418	

Only one DAC module (Z13A or Z13B) is used on a 69321B card. The module in use on any given card can be determined by noting the HP Part No. stamped on the module.

SECTION VII
CIRCUIT DIAGRAMS

7-1 INTRODUCTION

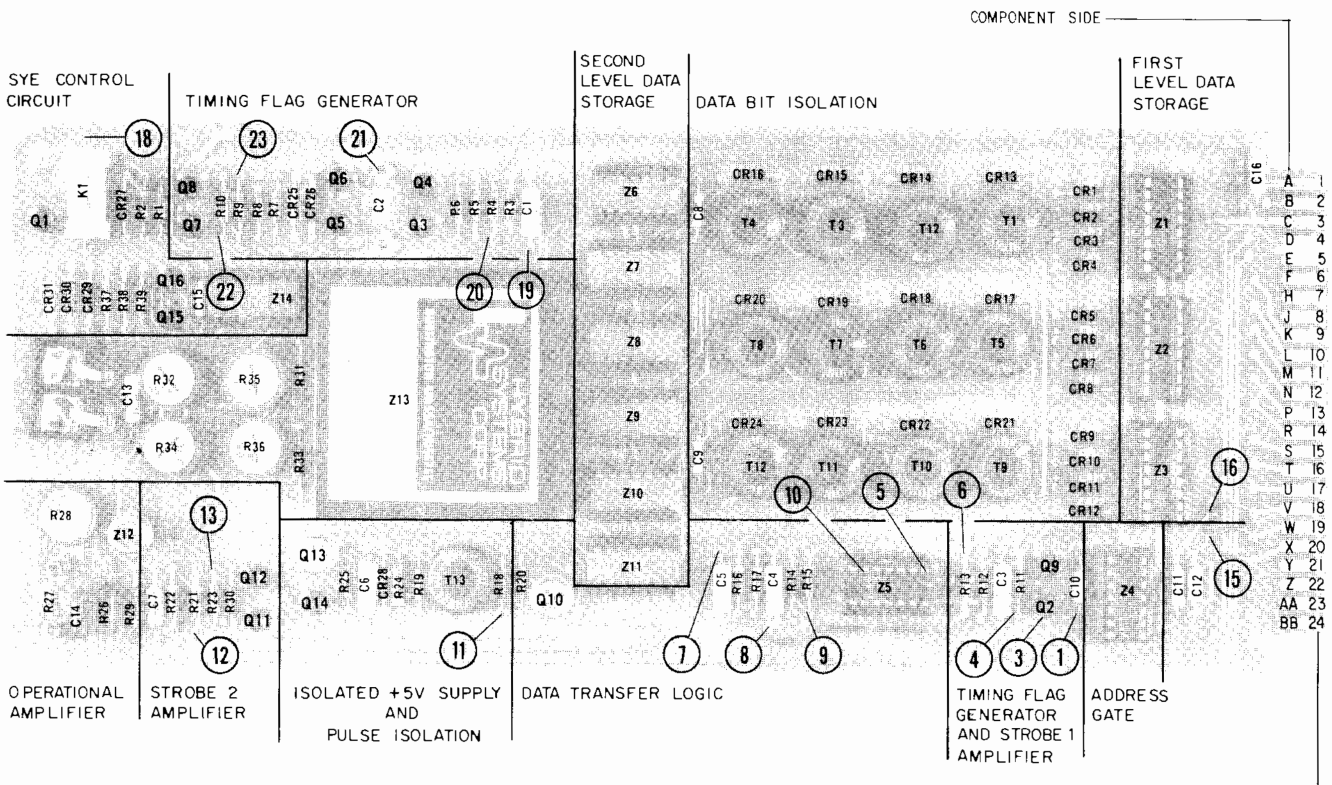
7-2 This section contains component location and schematic diagrams for the Model 69321B.

7-3 COMPONENT LOCATION ILLUSTRATION

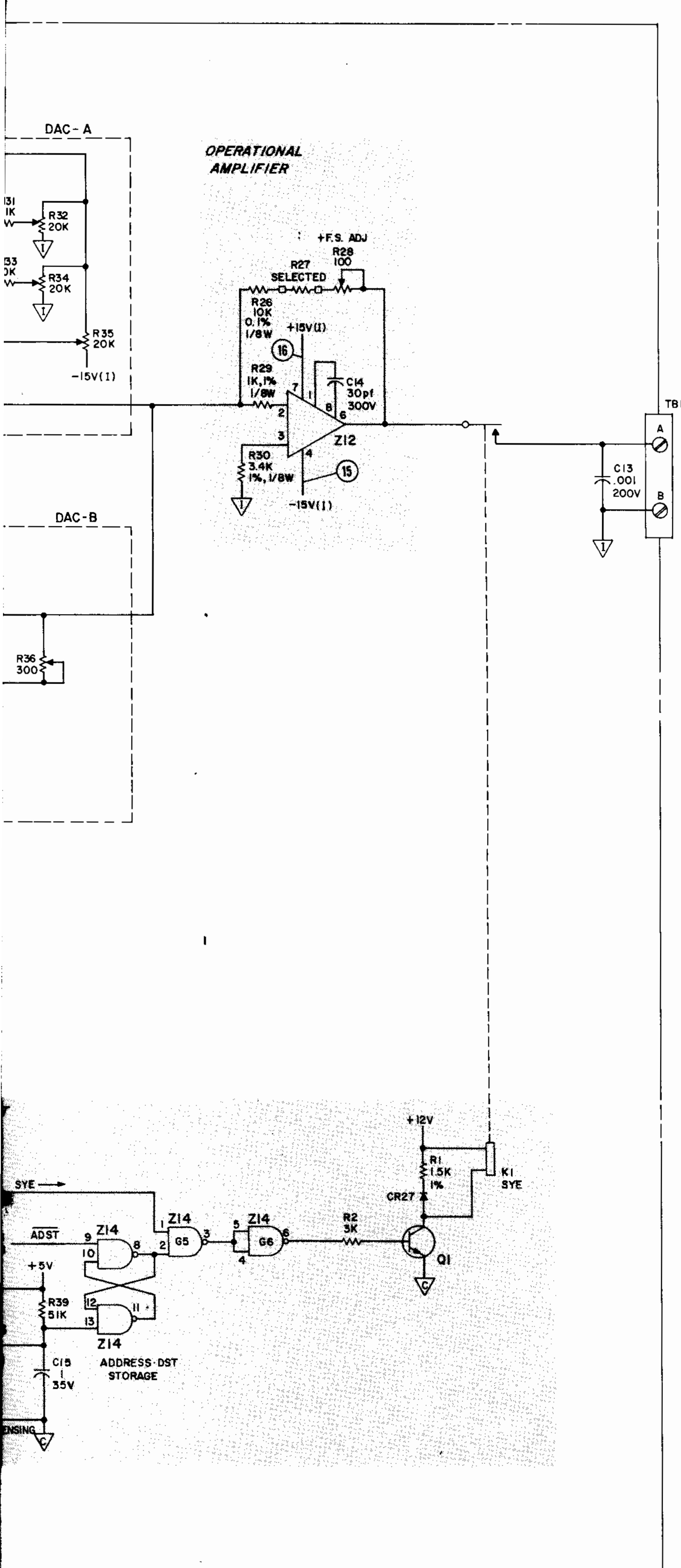
7-4 The component location illustration below shows the physical location and reference designations for parts mounted on the card.

7-5 SCHEMATIC DIAGRAM

7-6 The schematic diagram of the Model 69321B is given in Figure 7-1 The test points (encircled numbers) shown on the schematic diagram coincide with test points on the component location illustration

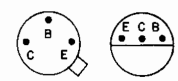


D/A Voltage Converter Card, Component Location



NOTES:

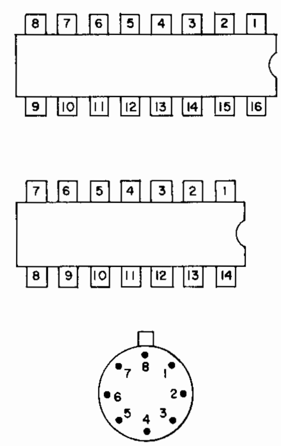
1. ALL RESISTORS ARE 1/4W, ±5%, UNLESS OTHERWISE INDICATED.
2. ALL CAPACITORS IN MICROFARADS, UNLESS OTHERWISE INDICATED.
3. +15V AND -15V POWER SUPPLIED BY VOLTAGE REGULATOR CARD (69351A) IN SLOT 600.
4. TO OBTAIN $\overline{CTF}$ PERIODS LONGER THAN 30μSEC, TRANSISTOR Q5 MAY BE ADDED TO TIMING FLAG GENERATOR BY REMOVING THE BASE-EMITTER JUMPER OF Q5. WHEN ADDED TO THE CIRCUIT, Q5 FUNCTIONS AS A CAPACITANCE MULTIPLIER (APPROX. EQUAL TO THE STAGE GAIN.) ALLOWING SMALL VALUE CAPACITORS TO GENERATE LONG TIME CONSTANTS.
5. PIN LOCATIONS FOR TRANSISTORS USED ON THIS CARD ARE AS FOLLOWS:



TO-5 PL-5

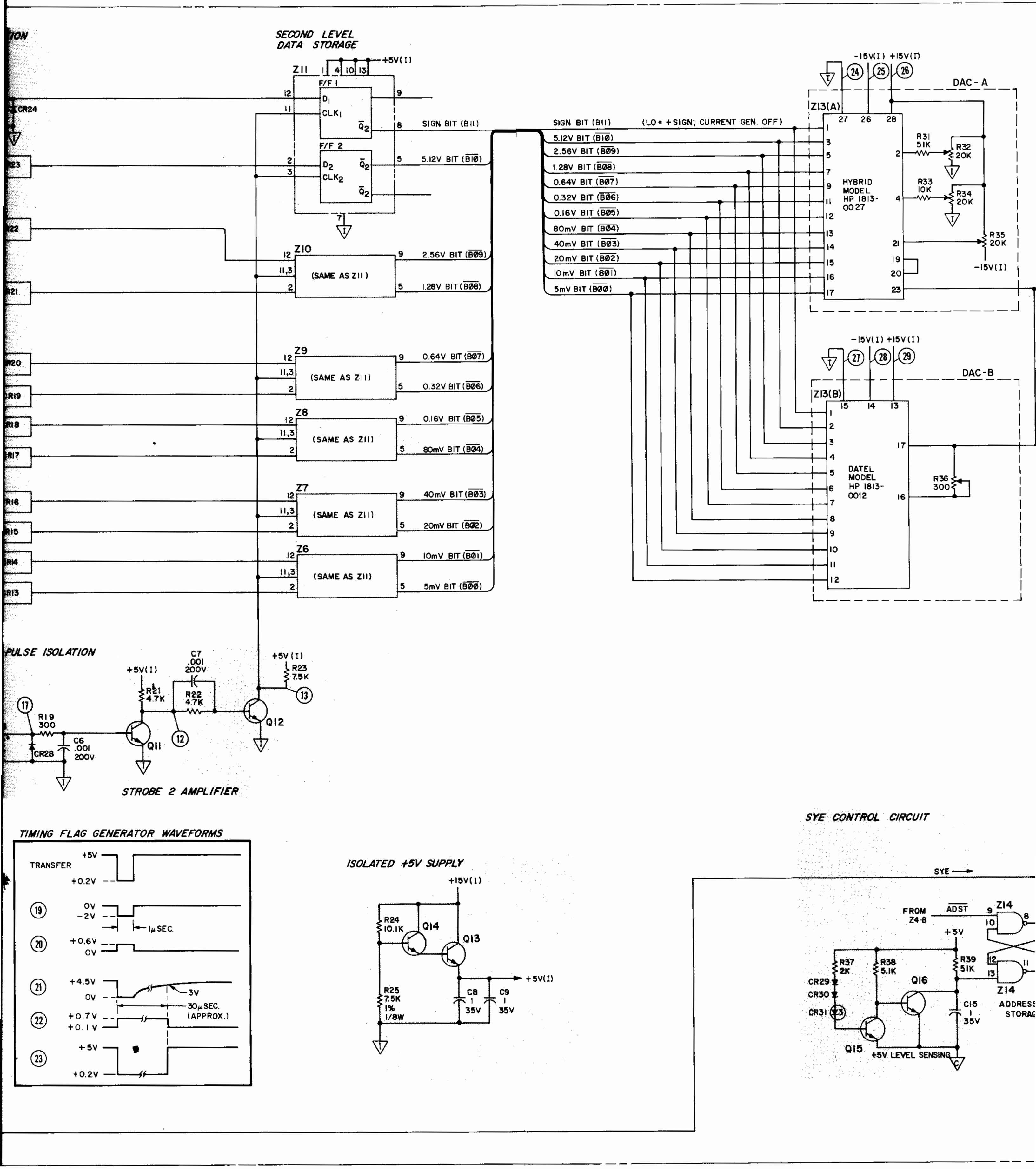
(TOP VIEWS)

6. PIN LOCATIONS FOR INTEGRATED CIRCUITS USED ON THIS CARD ARE AS FOLLOWS:



(ALL TOP VIEWS)

Figure 7-1. D/A Voltage Converter Card, Schematic Diagram

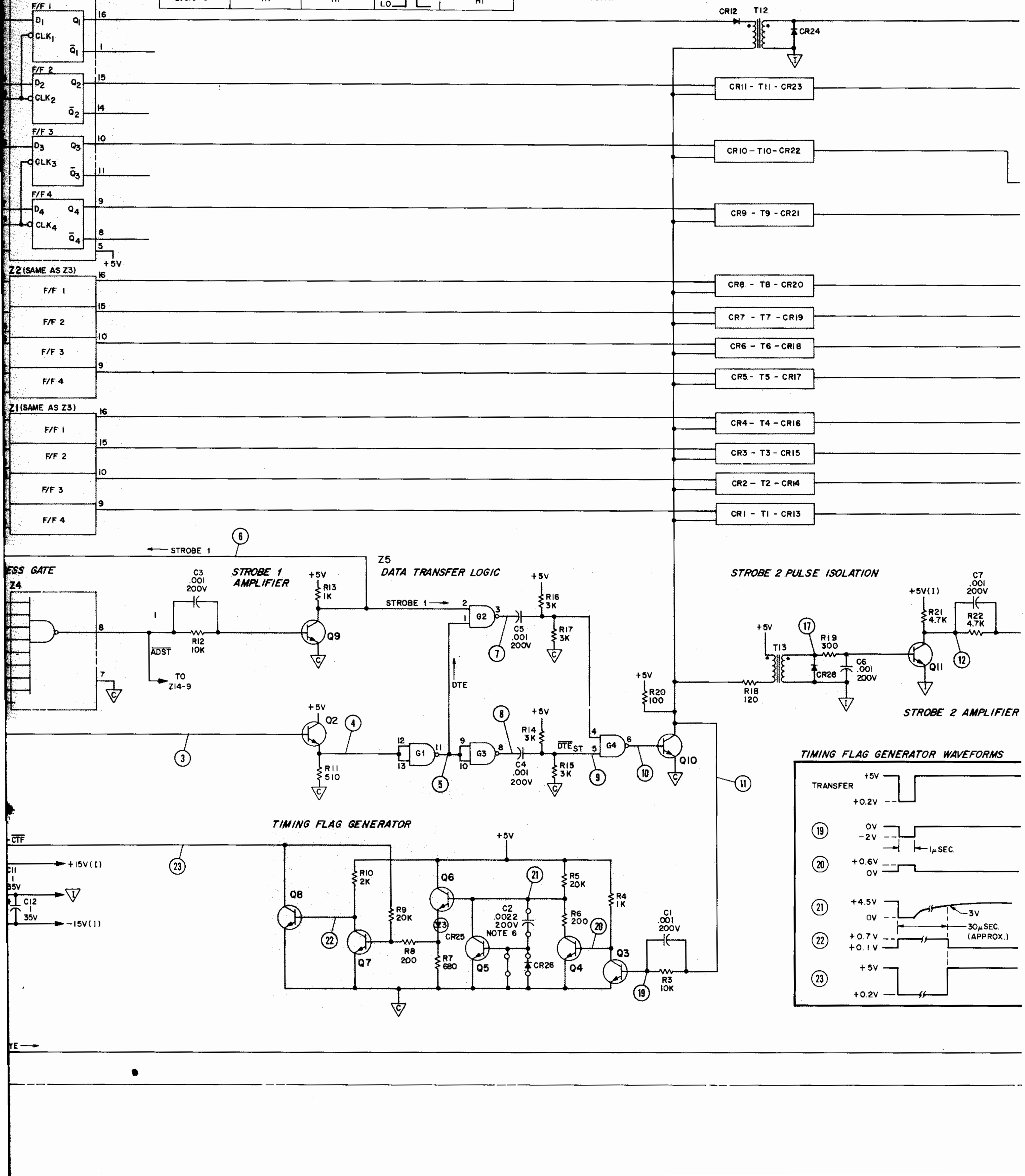

SECOND LEVEL DATA STORAGE
+5V(I)
Z11
F/F 1
F/F 2
SIGN BIT (B11)
5.12V BIT (B10)
CR24
Z10
(SAME AS Z11)
2.56V BIT (B09)
1.28V BIT (B08)
Z9
0.64V BIT (B07)
0.32V BIT (B06)
Z8
0.16V BIT (B05)
80mV BIT (B04)
Z7
40mV BIT (B03)
20mV BIT (B02)
Z6
10mV BIT (B01)
5mV BIT (B00)
(LO = +SIGN; CURRENT GEN. OFF)
-15V(I) +15V(I)
DAC - A
Z13(A)
HYBRID MODEL HP 1813-0027
R31 51K
R32 20K
R33 10K
R34 20K
R35 20K
-15V(I)
DAC - B
Z13(B)
DATEL MODEL HP 1813-0012
R36 300
PULSE ISOLATION
C7 .001 200V
R21 4.7K
R22 4.7K
R23 7.5K
R19 300
C6 .001 200V
CR28
Q11
Q12
STROBE 2 AMPLIFIER
TIMING FLAG GENERATOR WAVEFORMS
TRANSFER
+5V
+0.2V
0V
-2V
1μ SEC.
+0.6V
+4.5V
3V
30μ SEC. (APPROX.)
+0.7V
+0.1V
ISOLATED +5V SUPPLY
+15V(I)
R24 10.1K
Q14
Q13
R25 7.5K 1% 1/8W
C8 1 35V
C9 1 35V
SYE CONTROL CIRCUIT
SYE
FROM Z4-8
ADST
Z14
R37 2K
R38 5.1K
R39 51K
CR29
CR30
CR31
Q15
Q16
C15 1 35V
+5V LEVEL SENSING
ADDRESS STORAGE

CONVERTER CARD

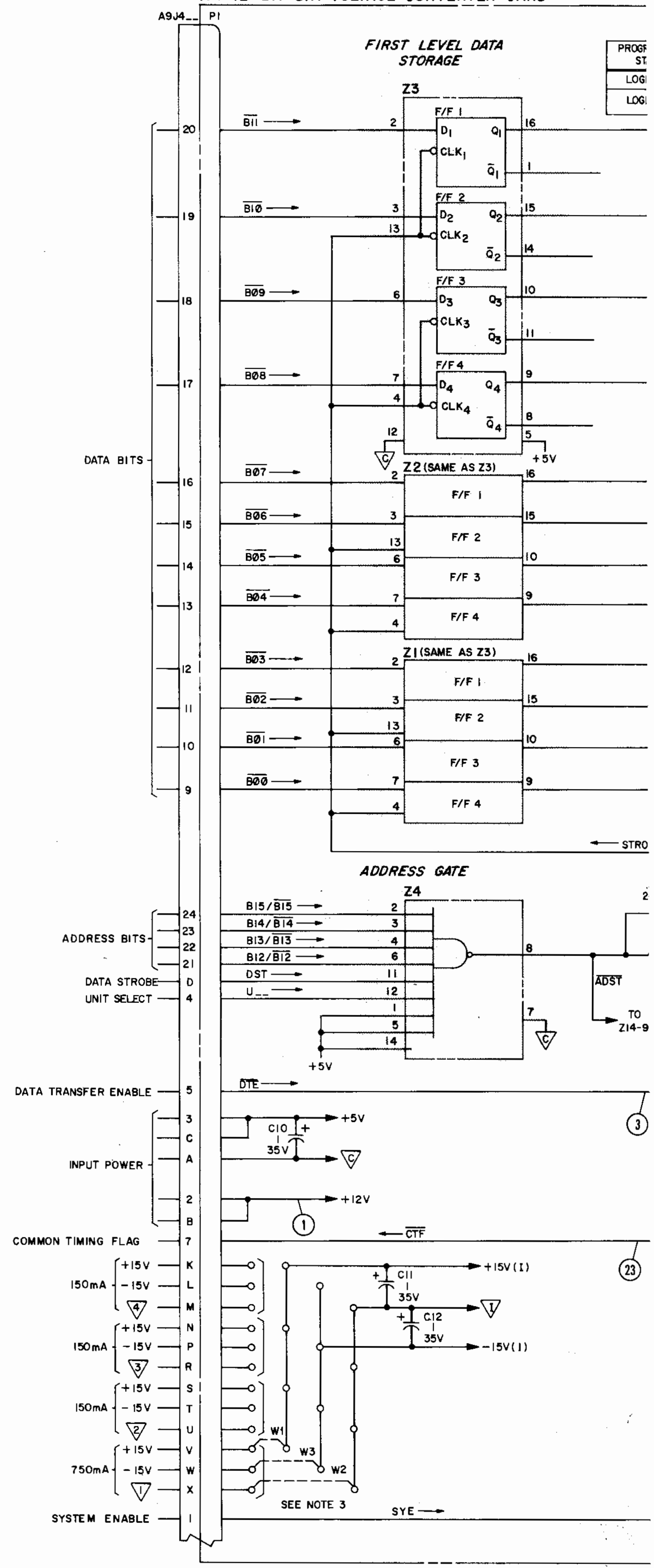
PROGRAMMED MAGNITUDE (BITS B00 THRU B10)

PROGRAMMED STATE	INPUT B__	1ST. LEVEL STOR. REG. Q-OUTPUT	ISO TRANS SECONDARY *	2ND. LEVEL STOR. REG. Q-OUTPUT *
LOGIC 1	LO	LO	LO	LO
LOGIC 0	HI	HI	HI / LO (pulse)	HI

NOTE: * AFTER TRANSFER PULSE IS GENERATED (SEE FIGURE 7-1 TIMING).
HI = +2.4V TO +5.5V.
LO = 0 TO +0.4V.



A4 12-BIT D/A VOLTAGE CONVERTER CARD



DATA TRANSFER CIRCUITS WAVEFORMS