APPENDIX A
IEEE-488 BUS INTERFACE
OPTION 4200-01

A-1. DESCRIPTION.

A-2. The IEEE-488 (GPIB) bus interface option permits external control of the instrument and data capture by a wide variety of compatible controllers. The instrument may be operated with other GPIB-compatible devices to achieve specific test automation goals, with no specialized control interface requirements for proper electrical operation.

A-3. Although no standard GPIB interface data formats have yet been established, certain common practices are achieving de-facto standard status. These practices have been adhered to in the design of the 4200-01 option interface formats and delineators, thereby assuring the user of format compatibility with almost all controllers, including the least expensive controllers.

A-4. CAPABILITY.

A-5. Certain sub-sets of full GPIB functions are specified in the IEEE-488 standard. The 4200-01 option includes the following capabilities:

SH1 Source Handshake
AH1 Acceptor Handshake
T7 Basic Talker, Unaddress if MLA, No Serial Poll or Talk Only capability
L3 Basic Listener, Unaddress if MTA
SR0 No Service Request capability
RL2 Remote-Local capability except LL0
PP0 No Parallel Poll capability
DC0 No Device Clear capability
DT0 No Device Trigger capability

NOTE

MLA = My Listen Address
MTA = My Talk Address
LLO = Local Lockout

A-6. INSTALLATION AND REMOVAL.

A-7. Option 4200-01 consists of interface board A23. Electrical interconnections are shown in Figure 6-8. To install and remove the interface board, proceed as follows:

a. Turn off power to the instrument.

b. Remove the screw that secures the top cover of the instrument, and slide the top cover back and off.

c. Position the interface board in the instrument so that the mounting holes in the interface board line up with the mounting posts in the instrument.

d. Connect the flat cable connector in the instrument to the front edge connector of the interface board.

e. Connect the power cable near the rear of the interface board, observing polarity.

f. Attach the interface board to the mounting posts in the instrument using six 4-40 binder head screws.

g. Install the top cover of the instrument, and install the top cover screw removed in step a.

h. If required, remove the three screws that attach the rear panel cover plate of the instrument, and replace it with a new cover plate.

i. Reverse the procedures of steps a through g to remove the interface board from the instrument.

A-8. OPERATION.

A-9. **Address Assignment.** Before using the instrument on the GPIB, it must be assigned a unique address. This address is set using the five right-most sections of rear panel address switch S1 in accordance with table A-1.

TABLE A-1. ADDRESS ASSIGNMENT

Decimal Address	Talk Code	Listen Code	Switch Setting 5	4	3	2	1
0	@	SP	0	0	0	0	0
1	A	!	0	0	0	0	1
2	B	"	0	0	0	1	0
3	C	#	0	0	0	1	1
4	D	$	0	0	1	0	0
5	E	%	0	0	1	0	1
6	F	&	0	0	1	1	0
7	G	'	0	0	1	1	1
8	H	(	0	1	0	0	0
9	I	)	0	1	0	0	1
10	J	*	0	1	0	1	0
11	K	+	0	1	0	1	1
12	L	,	0	1	1	0	0
13	M	-	0	1	1	0	1
14	N	.	0	1	1	1	0
15	0	/	0	1	1	1	1
16	P	0	1	0	0	0	0
17	Q	1	1	0	0	0	1
18	R	2	1	0	0	1	0
19	S	3	1	0	0	1	1

TABLE A-1. ADDRESS ASSIGNMENT (Cont.)

Decimal Address	Talk Code	Listen Code	Switch Setting 5	4	3	2	1
20	T	4	1	0	1	0	0
21	U	5	1	0	1	0	1
22	V	6	1	0	1	1	0
23	W	7	1	0	1	1	1
24	X	8	1	1	0	0	0
25	Y	9	1	1	0	0	1
26	Z	:	1	1	0	1	0
27	[	;	1	1	0	1	1
28	\	<	1	1	1	0	0
29	]	=	1	1	1	0	1
30	Z^	>	1	1	1	1	0

Address 31 (11111) will not be recognized and should not be used.

A-10. Talk Only Mode Selection. The talk only mode is used to communicate with an output device such as a printer without using a controller. When the TALK ONLY section of rear panel switch S1 is set to the 1 position, the instrument will send the result of each measurement over the bus automatically. The receiving device must be configured to operate in this mode.

A-11. Listen Only Mode Selection. The listen only mode is included primarily for troubleshooting interface and programming problems; it has little utility in normal operation. When the LISTEN ONLY section of rear panel switch S1 is set to the 1 position, the instrument will be a listener for all data mode transmission.

A-12. Command Response. In addition to Talk and Listen Address commands, the instrument responds to the following:

a. **Addressed Commands (Responds if Listen Addressed).**

Mnemonic	Name	Function
GTL	Go To Local	Enables panel control
GET	Group Trigger	Hold current measurement

b. **Listen Address Group.**

Mnemonic	Name	Function
UNL	Unlisten	De-address as listener

c. **Talk Address Group.**

Mnemonic	Name	Function
UNT	Untalk	De-address as talker

d. **Unencoded Commands.**

Mnemonic	Name	Function
IFC	Interface Clear	Initialize interface
REN	Remote Enable	Permits remote operation

A-13. Operating States. The instrument operates in two separate states, whether in local or remote control. One state is the measurement state, during which the instrument performs and displays measurements; the other state is the data entry/recall state, which is operative during number entry or after recall of stored information. When operating on the bus, it is important to remember that the instrument can send only that information which appears on the front panel display.

a. **Measurement Mode Functions.** The following functions change the measurement mode of the instrument:

Keyname	GPIB	Function
PWR MODE	P	Display measured power
dB MODE	B	Display measured dBm or dBr
AUTO	A	Set autorange mode
HOLD	O	Set range hold mode

b. **Data Entry/Recall Functions.** These functions enable entry or retrieval of numeric constants used by the instrument. Operation reverts to the measuring state after data storage.

Keyname	GPIB	Function
LO LIMIT	L	Low limit value, in dB
HI LIMIT	H	High limit value, in dB
dB CAL FAC	D	Calibration factor constant, in dB
GHz	F	Interpolate frequency/ calibration factor table
SENS	S	Select sensor data tables
CHNL	N	Select channel number
dB REF	R	dB reference level for dB mode

c. **Special Functions.** Special functions include the automatic zeroing, automatic calibration, and clear functions.

Keyname	GPIB	Function
ZERO	Z	Initiates an automatic zeroing cycle
CAL	K	Performs 1 mW automatic calibration
CLEAR	C	Clear numeric entry to zero

d. **IEEE-488 Bus Command Extensions.** The following functions are added to bus operation:

Name	GPIB	Function
ADR. ZERO	Y	Zero selected ranges (0-6)
SET RANGE	G	Set to selected range (0-6)

These commands must be preceded by an appropriate argument. The argument for Y is the span of ranges to be zeroed; for example, 26 specifies zeroing ranges 2 through 6. If only one range is to be zeroed, the argument must begin and end with the same code (e.g., 11Y to zero only range 1). The argument for G is the range number (0 = 10 nW to 6 = 10 mW for 4200-4 sensors) to be set. From execution of the Y command to measurement mode, the maximum time is as follows:

Command	Time
00Y	9.7 seconds
01Y	13.4 seconds
02Y	14.6 seconds
03Y	15.1 seconds
04Y	15.4 seconds
05Y	15.6 seconds
06Y	15.7 seconds

The "Y" command allows no wait time for a sensor to reach a stable zero before actual offset storage occurs.

NOTE

The G command sets the 4200 to an internal range which may not correspond to the range code output in the data string in Para. A-22. The table below relates internal and apparent range codes:

LEVEL		INTERNAL	APPARENT
+10 dB	1 mW	—	—
		6	
+6 dB	3.98 mW	—	
			6
0 dB	1 mW		—
		5	
			5
-10 dB	100 μW		—
-11 dB	79.4 μW	—	
			4
		4	
-20 dB	10 μW		—
-21 dB	7.94 μW	—	
			3
		3	
-30 dB	1 μW		—
-32 dB	631 nW	—	
			2
		2	
-40 dB	100 nW		—
-42 dB	63.1 nW	—	
			1
		1	
-50 dB	10 nW		—
-52 dB	6.31 nW	—	
			0
			↓
-60 dB	1 nW	0	
		↓	

A-14. REMOTE PROGRAMMING.

NOTE

It is assumed that the user is acquainted with GPIB principles and terminology. Refer to the controller instruction manual for the syntax needed to create specific bus commands and addressing sequences. All examples given apply to the HP 9825 calculator.

A-15. Bus Programming Syntax. The bus programming syntax mirrors the front panel keystroke sequence closely. Each key has been assigned an alphanumeric character, and sending that character is equivalent to pressing that front panel key. The resultant operation is indistinguishable from local control. Numerical values are translated by the GBIP interface so that commonly observed formats may be used. Fixed formats and floating point formats may both be used. These representations are converted to their equivalent fixed point values, and the sign information is post-fixed automatically, thereby ensuring that natural notations for numbers will be accepted by the instrument.

A-16. Suppose that it is desired to set the instrument to the PWR mode. The HP 9825 calculator could be programmed:

wrt 716, "P"

The "wrt" instructs the calculator to send data on the bus to one or more listeners. The number following is the address information; 7 is the calculator address, and 16 is the instrument address. (All examples in this appendix will use 16 as the instrument address, although any valid address can be assigned to the instrument.) When the calculator interprets the first part of the line, it will assert the ATN line to signify that commands or addresses will be sent on the bus. Following that, it will send three bytes or characters: Unlisten, the calculator Talk Address, and the instrument Listen Address. This information will configure both the calculator and the instrument for the data transfer. After the last command byte has been accepted, ATN will be released to the false state by the calculator. All information on the bus is interpreted as data in this mode. While in the data mode, the calculator will send the character "P" to the instrument. At the instrument, this will be interpreted as equivalent to pressing the MODE PWR key, and that function will be executed. Because there is no more data to be sent, the calculator will send a delimiter (the ASCII codes for Carriage Return and Line Feed). The instrument recognises the Line Feed as an end of message signal, and returns to the bus idle condition.

A-17. The preceding discussion of the sending of a single programming byte serves to illustrate two important points: every data transfer is preceded by a command/address preamble, and each transfer is terminated by a Line Feed character. In the preceding example, six characters were sent on the bus; only one was a programming byte.

A-18. The measurement mode functions (P, B, A, O) and the special functions (Z, K) do not expect any numeric value. These functions all execute as received. For example: the following will program dB and autorange mode:

wrt 716, "BA"

or

wrt 716, "AB"

Note that the sequence is unimportant, except that each function executes in the order it is received on the bus.

A-19. Suppose that the instrument is to be zeroed automatically, and then asked to send the reading in the

PWR and RANGE AUTO mode. The HP 9825 calculator could be instructed as follows:

```
wrt 716, "APZ"
red 716, V, S
```

The automatic zeroing cycle time is approximately 40 seconds. Until zeroing is completed, the instrument will be unable to respond with new data. The first line of the preceding instructions sets the operating mode and initiates the zeroing cycle. The last line reads the response from the instrument. The instrument response consists of two numeric values: the first value is the front panel reading, and the second is a status value (normally zero). These two numbers will be stored in the calculator variables (storage locations) V and S. Note that each data transmission from the instrument consists of two values. When the status value is non-zero, indicating an error condition, the data value will be set to zero. The program will normally test the status value to assure valid operating conditions.

A-20. Store/Recall Functions Syntax. The general syntax for store/recall functions is the same as the front panel sequence; if a numeric value immediately precedes the function, that value will be stored; otherwise, the existing stored value will be recalled to the front panel. These functions (L, H, D, F, S, N, R) thus operate in a dual mode.

A-21. Suppose that it is desired to store the current power level in dBm into the dBm reference so that all future readings will be referenced to the current value. Allowance must be made for the possibility that the current value is a dB relative value. To do this, the current dB value must be read, the existing dB reference must be recalled, the true dBm value must be computed, and this value must be stored into dB reference. The calculator could be instructed as follows:

```
red 716,V,S
wrt 716,"R"
red 716,X,S
V+X→Y
wrt 716,Y,"R"
```

Note that R is used twice in the program, the first time to obtain the existing value for the dB reference, and the second time to store the computed value. Also, note that the two read statements (red) each fetch a different value, the first value is the power value in dB, and the second is the dB reference.

A-22. Output Data Format. The data output of the instrument consists of two numeric values. The first is the numeric data in the display, and the second is the status information. The normal data output will have the following format:

abcsddddEsd,S,R(cr)(lf)

Where:

ab = mode (power in milliwatts = PW; dB = DM; dBr = DR)
c = channel (A = 1; B = 2; C = 3)
s = sign (+ or -)
dddd = data (four digits, each digit 0 - 9)
Esd = exponent, sign, digit
, = data delimiter
S = status digit:
- 0 = no error
- 1 = entry too small
- 2 = entry too large
- 3 = measurement under range
- 4 = measurement over range
- 7 = channel 3 over/under range

R = Range Code, coded as follows:
- 0 = -50 dBm or 10 nW
- 1 = -40 dBm or 100 nW
- 2 = -30 dBm or 1 μW
- 3 = -20 dBm or 10 μW
- 4 = -10 dBm or 100 μW
- 5 = 0 dBm or 1 mW
- 6 = +10 dBm or 10 mW
- 7 = +20 dBm or 100 mW

cr = carriage return
lf = line feed

A-23. Typical Application. Suppose that it is desired to measure insertion loss or gain with an instrument equipped with option 4200-03, channel 2 measures incident power, and channel 1 measures output power. The program, shown below, will request reference conditions and wait for the user to set them up. Following establishment of the reference, the program will loop on insertion loss/gain measurements. Each measurement is triggered by the user. Zeroing is prompted in the local mode at the beginning of the program. Reading errors, should they occur, will be signalled by a double beep from the calculator; normal measurements will give a single beep. There will be one print line per measurement. The reference value is not printed in this example.

Program Variable Usage:

P : = power measurement value
R : = range value
S : = status value
Z : = dummy input for prompts

Program Statements	Comments
0: cli 7	/clear interface
1: ent "zero chl,2",Z	/prompt for zeroing
2: rem 7	/enable remote
3: wrt 716, "INA0R2NA0R3N"	/0 dBref, auto - set ch 3
4: ent "ref measure",Z	/prompt to set up ref
5: red 716,P,S,R	/read ref value, status
6: if S >0;dsp "error',S; beep;gto 4	/test status
7: wrt 716,"IN",P,"R3N"	/set chl dBref = P
8: beep;ent "measure",Z	/prompt for measurement
9: red 716,P,S,R	/read measurement, status
10: if S >0;dsp "error",S;	/test status

beep;wait 100;gto8
11: prt P,"dB"; gto 8 /print measurement
12: end

A-24. The program in paragraph A-23 also measures reflection coefficient if channel 1 measures reflected power and channel 2 measures incident power. The reference conditions are established with a short at the test port of the directional coupler.

A-25. THEORY OF OPERATION.

A-26. General. Interface board A23 is a microprocessor-driven data interface which converts IEEE 488 bus compatible signals into control codes that operate the internal control bus of the instrument. It also converts instrument data into IEEE 488 compatible signals for use on the bus. All data transfers are handled by source and acceptor handshake protocols as defined by IEEE-488-1975.

A-27. Detailed Description. (See Figure A-1.) All data manipulation and IEEE 488 bus management are controlled by CPU IC3 on the instrument control board in conjunction with a micro-program stored in ROM IC1 on interface board A23. All data transfers are handled in parallel-to-parallel mode by register A23IC3. ROM A23IC1 is enabled by signal ROM-IF supplied from the control board. Port selection in register A23IC3 is controlled by address bits A0 and A1. Input signals $\overline{RD}$ (read), $\overline{WR}$ (write), and $\overline{CS}$ (chip select) to register A23IC3 are controlled by CPU IC3 on the instrument control board.

A-28. Port A of register A23IC3 operates with I/O selectors A23IC8 and A23IC9 and pull-up network A23IC12 for data in/out. Port B of register A23IC3 is used for mode selection and address setting; these functions are preset manually by means of bit switch A23S1. Port C of register A23IC3 is used for handshake controlling. Controller interface signals are defined as follows:

DAV	DATA VALID
NRFD	NOT READY FOR DATA
NDAC	NOT DATA ACCEPTED
ATN	ATTENTION
IFC	INTERFACE CLEAR
REN	REMOTE ENABLE
SRQ	SERVICE REQUEST
EOI	END OR IDENTIFY

A-29. When power is turned on, signals TALK and LISTEN are both set false by the software through gates A23IC6b and A23IC6c, respectively. (See Figure A-2.) When the associated controller sends commands, it sets

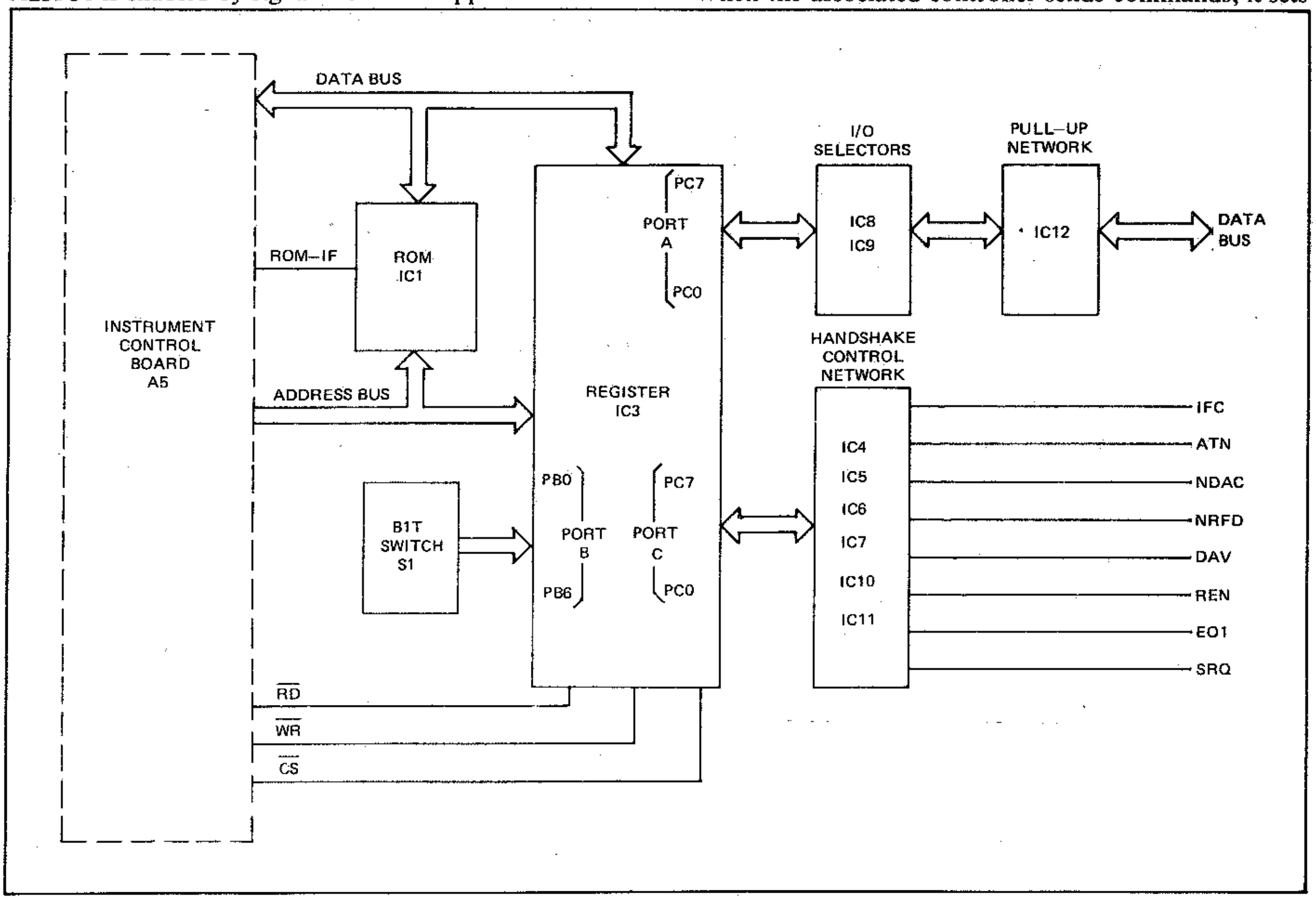

Figure A-1 IEEE 488 Bus Interface Option, Block Diagram signal ATN true. The true ATN signal resets flip-flop A23IC7b, and gates A23IC10a and A23IC10d are released for NRFD and NDAC signals.

A-30. If the interface board is addressed as a talker, a clock pulse is generated at pin 13 of register A23IC3. This clock pulse clocks flip-flop A23IC7a, the output of gate A23IC6b is set high, and gate A23IC10b is released for the DAV signal. If signal ATN or IFC is set true during talking, the output of gate A23IC6a is set low, flip-flop A23IC7a is ready, and signal TALK is set false by gate A23IC6b.

A-31. MAINTENANCE.

A-32. General. Signature analysis procedures to be used for checking of the contents of ROM A23IC1 are included in Section IV of the basic manual. (Refer to Table 4-7A or 4-7B.) Troubleshooting procedures for the remaining circuits on the interface board are provided in the following paragraphs.

A-33. Test Equipment Required. The following items of test equipment are required for troubleshooting the interface board:

a. Test PROM, Boonton Electronics Model 4200-01, part number 950005.

b. Test board, Hewlett Packard part number 59405-66503.

A-34. Test Procedure. Test the interface board as follows:

NOTE

It is assumed in the following procedures that the instrument being tested operates normally independent of the interface option.

a. Turn off power to the instrument.

b. Remove PROMs 0, 1, and jumper at J5 from the control board; remove PROM 2 from the interface board. Install test PROM Model 4200-01 in the socket vacated by PROM 0, observing orientation.

c. Turn on power to the instrument.

d. Connect the Hewlett Packard test board with the bus connector.

e. Make the following connections on the interface board with jumpers:

1. Connect ATN to GND.
2. Connect NDAC to D101.
3. Connect DAV to D104.
4. Connect SRQ to D102.
5. Connect NRFD to D103.

f. Press the MODE PWR key. Operation of integrated circuits IC5d, IC6a, and IC7a will be tested. Correct operation is indicated by an indication of 0001 on the instrument LED display; incorrect operation by an indication of 000c.

g. Press the RANGE AUTO key. Operation of integrated circuits IC5e, IC10d, and IC9 will be tested. Correct operation is indicated by an indication of 0002 on the instrument LED display; incorrect operation by an indication of 000c.

h. Press the dB LIMITS LO key. Operation of integrated circuits IC10b and IC9, and integrated circuits IC4d, IC4c, IC4b, and IC4a will be tested. Correct operation is indicated by an indication of 0003 on the instrument LED display; incorrect operation by an indication of 000c.

i. Press the CAL FACTOR dB key. Operation of integrated circuits IC5c, IC10c, and IC9 will be tested. Correct operation is indicated by an indication of 0004 on the instrument LED display; incorrect operation by an indication of 000c.

j. Press the SELECT SENS key. Operation of integrated circuits IC10a and IC9 will be tested. Correct operation is indicated by an indication of 0005 on the instrument LED display; incorrect operation by an indication of 000c.

k. Remove the jumper connection between ATN and GND. Connect a jumper between ATN and D106 and connect a second jumper between REN and D105.

l. Press the dB REF LEVEL dB key. Operation of integrated circuits IC8 and IC5f will be tested. Correct operation is indicated by an indication of 0006 on the instrument LED display; incorrect operation by an indication of 000c.

m. Press the MODE dB key. Operation of integrated circuits IC8 and IC5b will be tested. Correct operation is indicated by an indication of 0007 on the instrument LED display; incorrect operation by an indication of 000c.

n. Press the RANGE HOLD key. Operation of integrated circuits IC4b, IC4a, and IC8 will be tested. Correct operation is indicated by an indication of 0008 on the instrument LED display; incorrect operation by an indication of 000c.

o. Press the dB LIMITS HI key. Operation of integrated circuits IC9 and IC5a will be tested. Correct operation is indicated by an indication of 0009 on the instrument LED display; incorrect operation by an indication of 000c.

NOTE

Note and record the setting of the address switch before performing the following steps. Restore the original address switch settings upon completion of the interface board tests.

p. Set the address switch to 0101010. Press the CAL FACTOR GHz key. If operation is correct, the instrument LED display will show 0010; if incorrect, it will show 000c.

q. Set the address switch to 1010101. Press the SELECT CHNL key. If operation is correct, the instrument LED display will show 0011; if incorrect, it will show 000c.

r. Turn off power. Remove the test PROM from the PROM 0 socket on the control board. Reinstall PROM 0, PROM 1, and P5 on the control board, and PROM 2 on the interface board, observing orientation. Restore the address switch to its original settings.