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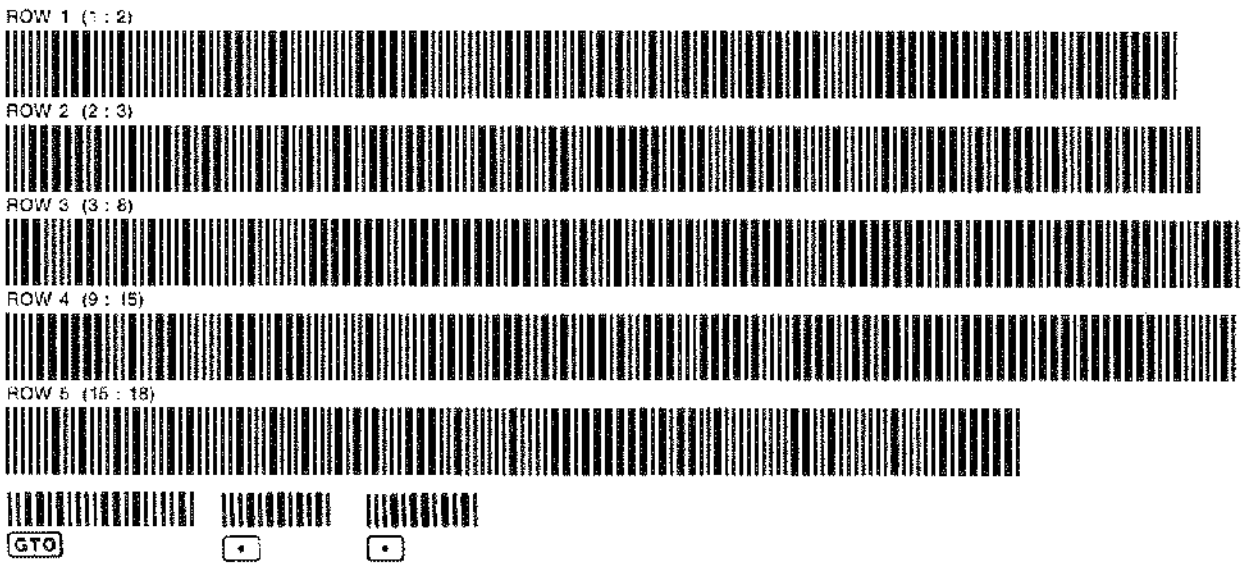
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TEMPERATURE MEASUREMENTS (Cont'd)

```
01*LBL "TTEMP"
02 XEQ "INI3421"
03 "CHANNEL ?"
04 PROMPT
05 "TEM"
06 "⊢"
07 ARCL X
08 OUTA
09 FIX 2
10*LBL 01
11 TRIGGER
12 IND
13 CLA
14 ARCL X
15 "⊢ DEG C"
16 AVIEW
17 GTO 01
18 .END.
```

TTEMP

PROGRAM REGISTERS NEEDED: 9




```
01*LBL "THERMO"
02 XEQ "INI3421"
03 "CHANNEL?"
04 PROMPT
05 "DCV"
06 "⊢"
07 ARCL X
08 OUTA
09 IND
10 STO 01
11 "REF"
12 OUTA
13 IND
14 CLA
15 ENTER↑
16 ENTER↑
17 2.3 E-8
18 *
19 5.053 E-5
20 +
21 *
22 RCL 01
23 +
24 ENTER↑
25 ENTER↑
26 ENTER↑
27 3.0848254 E16
28 *
29 -5.3719255 E15
30 +
31 *
32 3.79243843 E14
33 +
34 *
35 -1.38014121 E13
36 +
37 *
38 2.7150838 E11
39 +
40 *
41 -2.831128 E9
42 +
43 *
44 1.821297 E7
45 +
46 *
47 -1.75117 E5
48 +
49 *
50 1.97509 E4
51 +
52 *
53 -3.6 E-1
54 +
55 ARCL X
56 "⊢ DEG C"
57 AVIEW
58 .END.
```


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THERMO COUPLE

PROGRAM REGISTERS NEEDED: 32

ROW 1 (1 : 2)



ROW 2 (2 : 3)



ROW 3 (3 : 8)



ROW 4 (9 : 15)



ROW 5 (16 : 19)



ROW 6 (19 : 27)



ROW 7 (27 : 29)



ROW 8 (29 : 32)



ROW 9 (32 : 33)



ROW 10 (34 : 35)



ROW 11 (35 : 38)



ROW 12 (38 : 41)



ROW 13 (41 : 44)



ROW 14 (44 : 47)



ROW 15 (47 : 51)



ROW 16 (52 : 56)



ROW 17 (56 : 58)





GTO

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DATA LOGGER

The following data logger program (LOGGER) illustrates the power and flexibility of the 3421A and and 41C/CV combination. The program takes ten sets of DC voltage measurements from ten consecutive channels of the 3421A, for a total of 100 readings. The readings are stored on a cassette tape for future reference. Channel numbers measured are 10 through 19.

The second program, READ, demonstrates how easily data can be read from the cassette and listed on a printer. Again, there are several ways to enhance this program. For example, you could add a routine to plot the data on the printer instead of simply listing it. Of course, the LOGGER and READ could be combined to print or plot the data as it is being recorded.

Running The LOGGER Program

Make certain that the interface loop connections have been made between the 3421A, 41C/CV calculator, 82161A Digital Cassette Drive, and the 82162A Printer. Turn all of the devices on.

Before any data can be stored on the cassette tape, the tape must be initialized. This is done by executing the NEWM command (NEW Medium). Refer to the -hp- 82160A HP-IL Module Owners Manual.

When all connections have been made to the device under test and you are ready to begin, type:

XEQ ALPHA LOGGER ALPHA

How the Programs Work

Logger

Space for storing 100 readings must be allocated on the cassette tape. This space (or file) is created and given the name DATA. This is done in lines 03 through 05. Lines 06 and 07 are used to return to the beginning of the DATA file on the cassette prior to storing the measured data.

Register 00 is used as a loop counter to take ten sets of readings. The value 1.010 is stored in register 00 (lines 08, 09) and is incremented and tested in line 25.

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Register 01 acts as a channel counter to specify which channel is to be measured. The value 10.019, representing channels 10 through 19, is stored in register 01 (lines 11 and 12). Registers 10 through 19 are temporary storage registers for the measurements taken. Line 20 stores the data in the register pointed to by register 01. Register 01 is incremented after each reading to point to the next empty register and channel to be measured by line 21.

Remember that program line 11 specified register 19 as the last register to store readings. If register 01 points to register 20 then the program prepares to store the ten readings on the cassette. Line 23 calls out registers 10 through 19 as data storage registers. The WRTRX command (line 24) writes the data, register by register, onto the cassette tape.

Register 00 is tested in line 25 to see if ten sets of ten readings have been made. If not, the program loops back (line 26) to label 00 (line 10). When ten sets of readings have been made the program ends.

Read

Lines 2, 3, and 4 are used to locate the beginning of the DATA file on the cassette tape. Register 00 is used to count the ten 'sets' of readings. The value 1.010 is stored in register 00 (lines 05 and 06) and is tested in line 12.

Lines 08 and 09 are used to read the measured values into registers 10 through 19. Note that these are the same registers used in the logger program to specify the channels to be measured. These particular registers are used in this program so that when the values are printed, lines 10 and 11, the printout will show the channel number along with the reading from that channel.

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DATA LOGGER (Cont'd)

```
01*LBL "LOGGER"
02 XEQ "INI3421"
03 "DATA"
04 100
05 CREATE
06 0
07 SEEKR
08 1.010
09 STO 00
10*LBL 00
11 10.019
12 STO 01
13*LBL 01
14 RCL 01
15 FIX 2
16 "DCV"
17 ARCL X
18 OUTA
19 IND
20 STO IND 01
21 ISG 01
22 GTO 01
23 10.019
24 WRTRX
25 ISG 00
26 GTO 00
27 .END.
```

LOGGER

PROGRAM REGISTERS NEEDED: 12

ROW 1 (1 : 2)



ROW 2 (2 : 4)



ROW 3 (4 : 10)



ROW 4 (11 : 16)



ROW 5 (16 : 22)



ROW 6 (22 : 26)



ROW 7 (27 : 27)





GTO

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DATA LOGGER (Cont'd)

```
01*LBL "READ"
02 "DATA"
03 0
04 SEEKR
05 1.010
06 STO 00
07*LBL 01
08 10.019
09 READRX
10 10.019
11 PRREGX
12 ISG 20
13 GTO 01
14 .END.
```

READ

PROGRAM REGISTERS NEEDED: 7

ROW 1 (1 : 2)



ROW 2 (3 : 8)



ROW 3 (8 : 11)



ROW 4 (12 : 14)





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USING THE ADVANCED COMMANDS

The Advanced Commands given in the Command Table (the blue pages at the end of the previous chapter) can also be executed from the 41C/CV. They follow the same constraints as the Standard Commands. Refer to the section on Programming Hints earlier in this chapter.

When more than one command is sent to the 3421A, such as 'F1RAZ1', the commands are executed as they arrive. This is especially important to understand with trigger commands. For example, if you sent 'T1T3', the T1 command would be asserted only momentarily until the T3 command arrived. For this reason, it is best to make the trigger command the last statement in the command string. In this way, the 3421A will be set up for the measurement before the internal voltmeter is trigered for the measurement.

When a multicharacter command is received by the 3421A, and one character does not fit into the syntax of the command, a syntax error will result. For example, if you send 'FR2'; the 3421A does not recognize 'FR' as a legitimate command. Therefore there will be a syntax error. However, the 3421A will attempt to execute any command it can, and since it recognizes 'R2' it will go to the R2 range.

A terminator may have to be added between some commands to act as dividers. Suitable terminators are colons(:) and semicolons (;). For example, when specifying a channel list followed by other commands, a terminator must be used: 'LS0-9:F1RAZ1'.

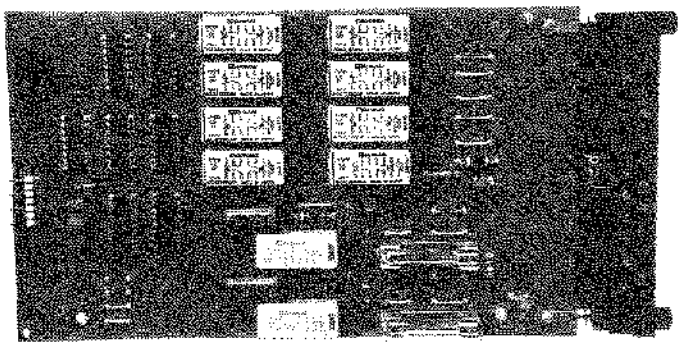
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CHAPTER 5
44462A
10 Channel Multiplexer Option
Option 020
Option 021
Option 022

Introduction

Each 44462A assembly provides 10 channels to switch signals to the 3421A voltmeter, counter, or to external instruments. Each relay consists of two sets of low thermal offset contacts; one set for the HIGH terminal and one for the LOW terminal. The relays exhibit low thermal offset characteristics making them ideal for precision low level measurements of thermocouples, etc. In addition, two of the relays may be configured as actuators for controlling motors, alarms, etc.

With two 44462A assemblies in the 3421A, 4-wire resistance measurements may be made. This is because the 3421A allows channel pairs (1 per relay assembly) to be closed simultaneously. This is important when measuring RTD's or other resistive transducers.



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In this chapter you will learn how to employ the 44462A 10 Channel Multiplexing Assembly for various types of analog signal measurements and actuating. The powerful 3421A instruction set makes the option easy to use. Typical uses include voltage, temperature, 2- and 4-wire resistance, and frequency measurements. Most examples are accompanied by a BASIC language program (such as used by the HP-85) to demonstrate the instruction. You'll also see many application examples such as using attenuators and 4-20mA current loop transducers.

Channels

A channel, as used in this chapter, refers to an individual relay on a 44462A assembly. Therefore, when we speak of closing a channel, we are referring to closing a relay. Channel addresses are used to indicate a specific relay in a specific slot in the 3421A. In other words, channel address 12 means channel number 2 in slot 1. We will see more on channel numbering later.

Most of the channels on the 44462A can be configured in different ways to satisfy particular requirements. For example, the first two channels on each assembly can be configured either as actuators (a simple switch closure to turn on or off) or as multiplexers (to connect analog signals to the voltmeter or counter). When properly configured, the 3421A is able to sense which channels are configured as actuators and which channels are multiplexers.

All but the last two channels on each assembly can have attenuators built into the signal path. This will be discussed later in this chapter.

IMPORTANT NOTICE ON CHANNEL CONFIGURATION

When a 10 Channel Multiplexer Assembly is ordered factory installed, it can have one of three different configurations (Option 020, 021, or 022). This is outlined in the following table.

Option #	Channels	Configuration
020	0,1	Actuators
	2-9	Multiplexing
021	0	Actuator
	1-9	Multiplexing
022	0-9	Multiplexing

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When a 10 Channel Multiplexer Assembly is ordered for field installation (44462A), channels 0 and 1 will be configured as actuators and channel 2-9 will be configured as multiplexers.

Regardless of how the 10 Channel Multiplexer Assembly is ordered, the built-in 10:1 divider of channel 2 is bypassed at the factory (i.e., jumper in the "OUT" position). On early versions of Option 020 and Kit 44462A, the 10:1 divider was in place (i.e., jumper in the "IN" position).

The factory configuration may be changed to fit your application. Jumper and channel configuration information for the service technician is provided in Chapter 8 of this manual. The simplified schematic in Figure 5-1 shows the factory configuration.

WARNING

Only qualified personnel with a knowledge of electronic circuitry should install or reconfigure the option boards. Installation and configuration information for this option board is provided in Chapter 8.

Channel Numbering and Addressing

Channel numbers are repeated on each 44462A assembly. This is shown by the numbering on the terminal block edge connector. Channel addresses, however, are determined by which slot the 44462A assembly is in. For a 44462A assembly in slot 1, for example, channel number 7 would be addressed as 17. The following table shows the channel addressing scheme for the three different slots.

Channel # as shown on the terminal block	Channel address if assembly is in slot #:		
	Slot 0	Slot 1	Slot 2
0	00	10	20
1	01	11	21
2	02	12	22
3	03	13	23
4	04	14	24
5	05	15	25
6	06	16	26
7	07	17	27
8	08	18	28
9	09	19	29

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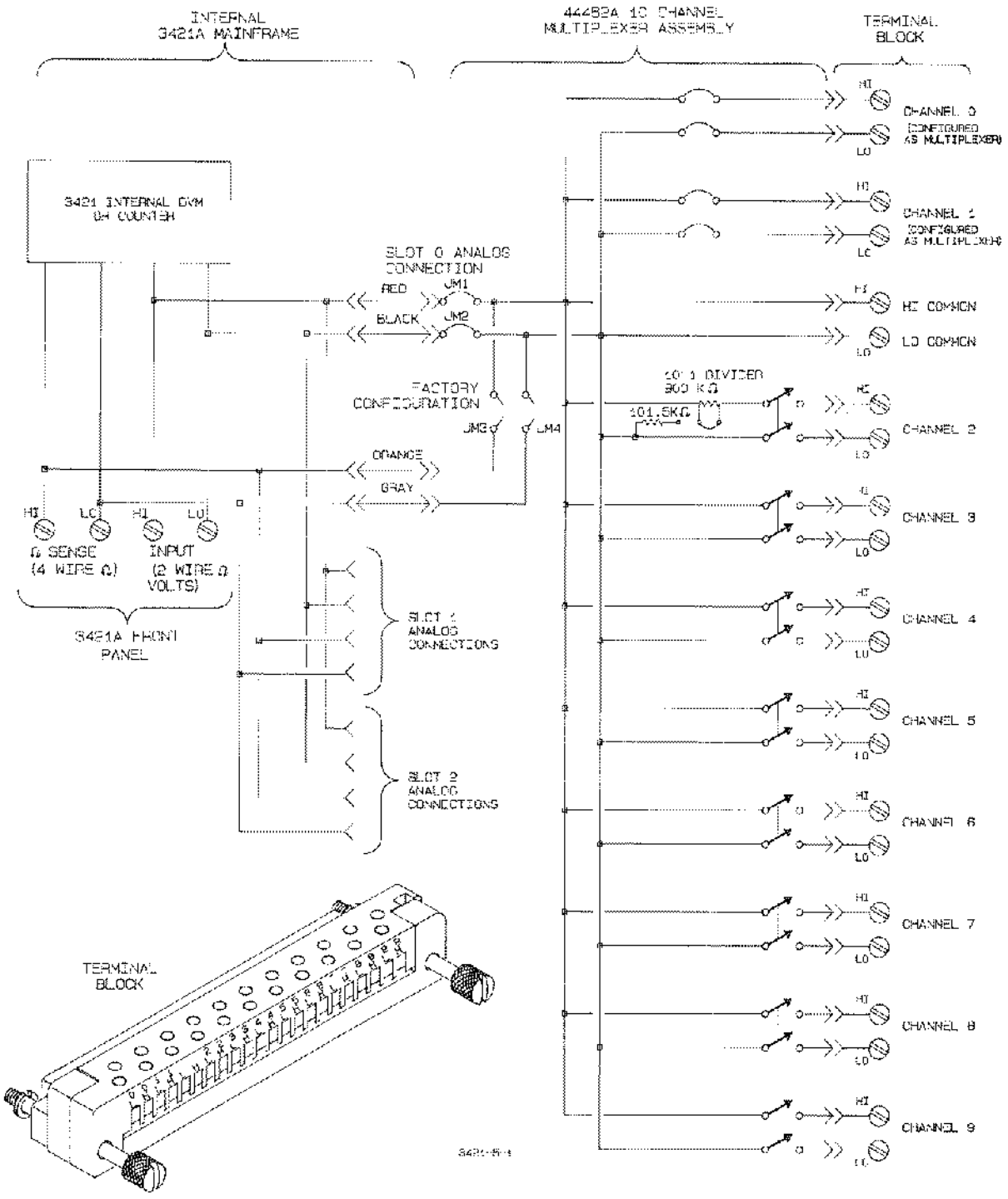


Figure 5-1. Simplified Schematic

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Channel # as shown on the terminal block	Channel address if assembly is in slot #:		
	Slot 0	Slot 1	Slot 2
0	00	10	20
1	01	11	21
2	02	12	22
3	03	13	23
4	04	14	24
5	05	15	25
6	06	16	26
7	07	17	27
8	08	18	28
9	09	19	29

Channel List

Many of the commands described in this chapter use an optional "Channel List." The channel list is a convenient method of grouping several channels under one type of measurement. If you need to measure the DC Voltage from several channels, you could use the command DCV[x,y,...z]. Where [x,y,...z] represents a list of channel addresses. The channel list can be loaded with a maximum of 30 channel addresses.

The channel list must follow a set of guidelines:

1. The default channel list (asserted at power on or reset) is all multiplexer addresses in numerical sequence. The channel list can be loaded with multiplexer channels by the DCV, ACV, TWO, FWO, TEM, FRQ, LS, or LP commands. It can also be loaded with digital input bit numbers by the BIT command.

2. Channel addresses are separated by commas (i.e., DCV2,3,4,5). However, a dash may be used to specify a contiguous set of channels (i.e., DCV2-5). When using the Advanced Commands, any command that specifies a channel must be separated from subsequent commands by either a colon (:) or a semicolon (;). For example, F1RA1LS5-9;T3. Do not use a comma.

3. To take burst readings on one channel, load the channel list with the channel number. For example, to take a burst of 30 DC voltage readings from channel 5, execute DCV5-5. If the last character in the command string is a comma, an error will be generated.

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4. The command mnemonic determines what type of channel can be loaded into the channel list. In other words, if channel 1 is configured as an actuator, it should not be specified for any type of measurement (i.e., DCV1 or BIT1). If an attempt is made to load the channel list with an improper type of channel, a syntax error will be generated and the command aborted. One possible exception would be if a contiguous set of channels is specified, such as x-y, and some channels within that range (inclusive of x and y) are the wrong type of channels for the command. In such a list, the improper channels will not be loaded into the list, but the properly configured channels will be loaded. No error will be generated.

5. Leading zeros are ignored, that is, DCV00019 is the same as DCV19.

6. All syntax following a decimal point is ignored except for comma, dash, semicolon, Carriage Return (cr) or Line Feed (lf). DCV2.345 means DCV2.

7. Exponents are not allowed and cause a syntax error. The command will be aborted.

8. No more than 30 channels are accepted into the channel list. Legal numbers are 00 through 29.

9. All lower case letters are interpreted as upper case. In other words, Dc V 21 is interpreted the same as DCV21.

Measurements

Multiplexing (also known as switching or scanning) involves simply switching various inputs through the relays on the 44462A assembly to either the internal voltmeter or counter. The type of command (DCV for DC Volts, FRQ for frequency, etc.) determines where the signal is measured. Note also that signals can be input through the front panel terminals. This should only be done though if no relays are closed. Conversely, signal input through the relays can be output through the front panel terminals to an external voltmeter, counter, etc.

WARNING

All power sources being measured by the 3421A must be limited to 150VA maximum.

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WARNING (Cont'd)

Damage to the 3421A or external devices may result if voltage inputs are made through the front panel terminals and the relay inputs simultaneously. Therefore, under no circumstances should a voltage be input through the front panel terminals while at the same time a voltage is being input through the relay assembly.

The following examples of using the 44462A multiplexer assembly are broken down into four measurement types: Voltage, Resistance, Temperature (using thermocouples), and Counter functions. Succeeding these is a brief discussion on attenuators. The 3421A Commands associated with each of these areas are also discussed. Actuators will be discussed later in this chapter. All program examples are for a BASIC language controller, specifically the HP-85.

Voltage Measurements

Voltage measurements, whether AC or DC, are easily made with the 44462A assembly. Each channel on the assembly is provided with independent HIGH and LOW connections on the terminal block. Furthermore, Channels 0 through 7 may be configured with a divider network to attenuate voltages. In fact, Channel 2 is provided with a jumper selectable 10:1 divider built-in. Later in this chapter you will see how attenuators are used. Information for the service technician to install the attenuators is provided in Chapter 8.

WARNING

In the power down mode, all relays on the 44462A Assemblies remain in their pre-power down state. In other words, if a relay (actuator or voltage input, etc.) was closed before power down, it will remain closed after power down.

DCV[x,y,...z]

The DCV command sets the voltmeter to DC volts function, autorange, autozero on, and 5½ digits resolution. The parameter [x,y,...z] sets up an optional channel list. A reading is taken from each channel and stored in the sequence of the channel list. When the 3421A is addressed to talk, the readings are sent in the order they were taken, i.e., the channel list order. The DCV command always opens the last channel before closing the next channel in the list. When the last channel has been measured, that channel stays closed. This is true unless no channel list is received. In that case, channels remain in the same state and one reading is taken.

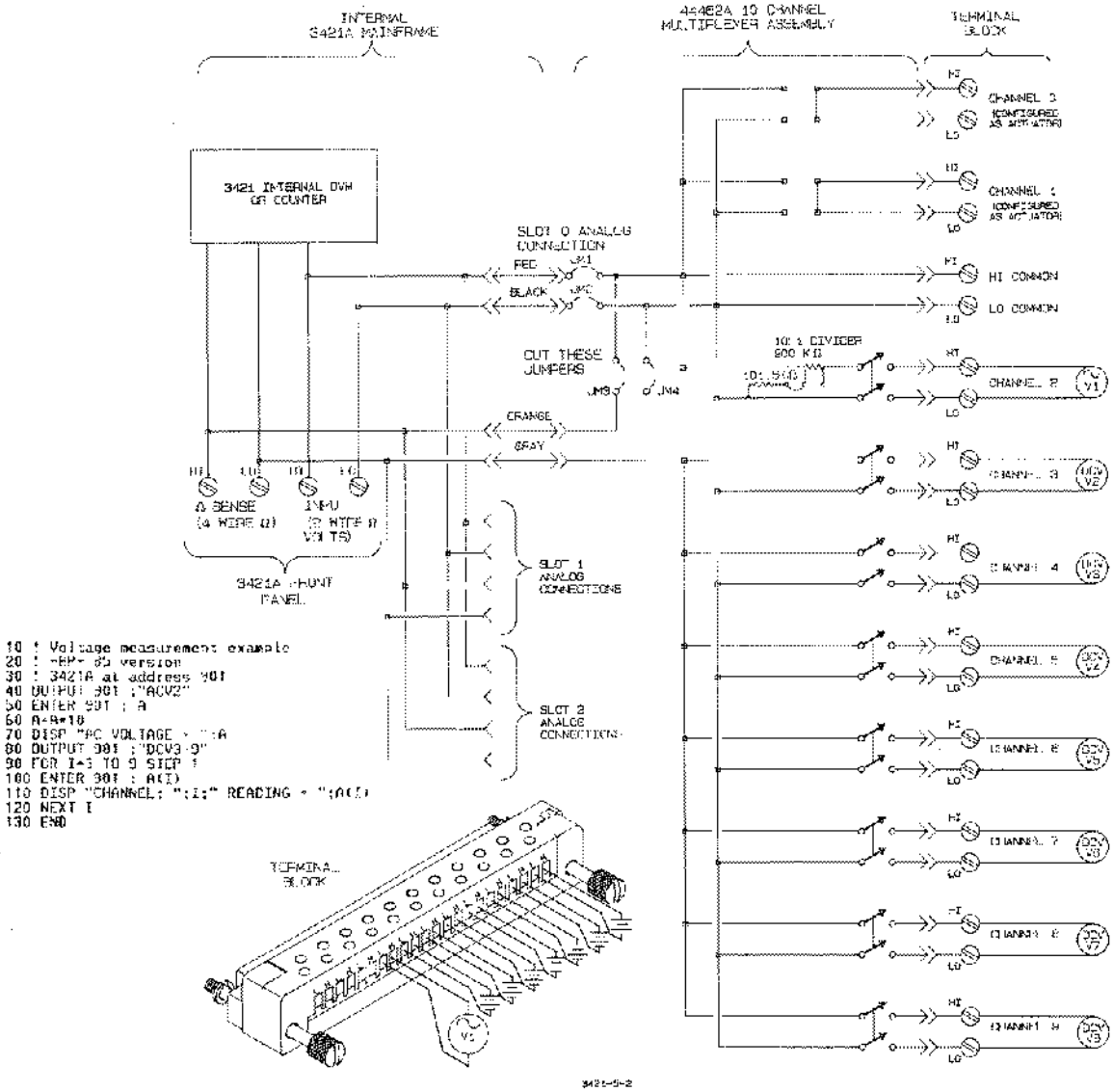
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ACV[x,y,...z]

The ACV command acts just the same as the DCV command except that the AC volts function and 4½ digit resolution are selected.

An example of using the 44462A assembly to measure an AC voltage on channel 2 and DC voltages on channels 3 through 9 is demonstrated in the following figure. Remember that the relay assembly is in slot 0 of the 3421A.

Notice in Figure 5-2 that the 10:1 divider is used for the AC voltage measurement. Therefore, the measurement taken on channel 12 must be multiplied by 10 to get the actual voltage. The program shown beside the illustration shows how easy it is to make the measurements and return the results to the calculator.




```
10 ! Voltage measurement example
20 ! HP-IB 98 version
30 ! 3421A at address 901
40 OUTPUT 901 ;"ACV2"
50 ENTER 901 ; A
60 A=A*10
70 DISP "AC VOLTAGE = ";A
80 OUTPUT 901 ;"DCV3-9"
90 FOR I=3 TO 9 STEP 1
100 ENTER 901 ; A(I)
110 DISP "CHANNEL: ";I;" READING = ";A(I)
120 NEXT I
130 END
```

Figure 5-2. Voltage Measurements

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Resistance Measurements

Resistance measurements, like DC voltage measurements, are easily made with the 44462A assembly. Resistance measurements are made by the 3421A sourcing a current through the unknown resistance. The DC voltmeter measures the attendant voltage drop across the resistor and calculates the resistance. Two types of resistance measurements can be made by the 3421A; 2-wire and 4-wire.

The 2-wire ohms mode is used most commonly when the resistance of the test leads is not critical. Inaccurate results may occur when using the 2-wire ohms mode if the resistance of the test leads is very high. For example, suppose you are making a temperature measurement using a thermistor (2.252 kOhms @ 25°C). This thermistor is 40 feet away from the 3421A. At 20°C the thermistor will have a resistance of 2814 ohms. However, at 20°C, 40 feet of #24 A.W.G. copper wire has a resistance of approximately 1.02 ohms. Two wires, each 40 feet long would produce an error of 2.04 ohms. Using a 2-wire ohms measurement results in a .4% resistance error. In addition, the 3421A has a 2-wire Ohms offset of up to 4 ohms, adding an other .15% error. See Figure 5-3.

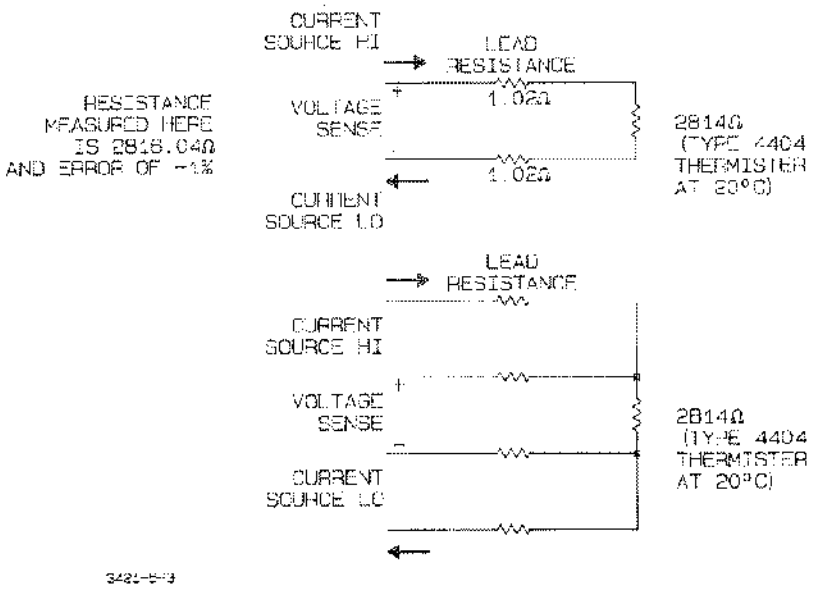


Figure 5-3. 2-Wire vs. 4-Wire Resistance Measurements

The use of a 4-wire ohms measurement eliminates the error caused by the test lead resistance. The current through the thermistor is the same regardless of the lead resistance but the voltmeter measures only the voltage drop across the thermistor, not across the combined lead resistance. The 4-wire measurement is essential where long lead lengths are present or where the highest accuracy is desired. Two 44462A relay assemblies are needed for 4-wire resistance measurements, one with the 4-Wire Ohms Source jumpers in place and the other with the 4-Wire Ohms Sense jumpers in place.

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TWO [x,y,...z], 2-Wire Resistance Measurements

Figure 5-4 illustrates the procedure for making 2-wire resistance measurements. The command for a 2-wire measurement is TWO [x,y,...z]. TWO represents Two Wire Ohms. The parameter [x,y,...z] is the channel list to specify which channels to make the measurement on. In the figure below, channels 2 through 5 and channels 8 and 9 are used for the resistance measurement. Therefore, the command to make those measurements could be: TWO2-5,8,9. This is demonstrated in the sample program associated with the illustration.

The TWO[x,y,...z] command acts identical to the DCV[x,y,...z] command except that a 2-wire resistance measurement is made.

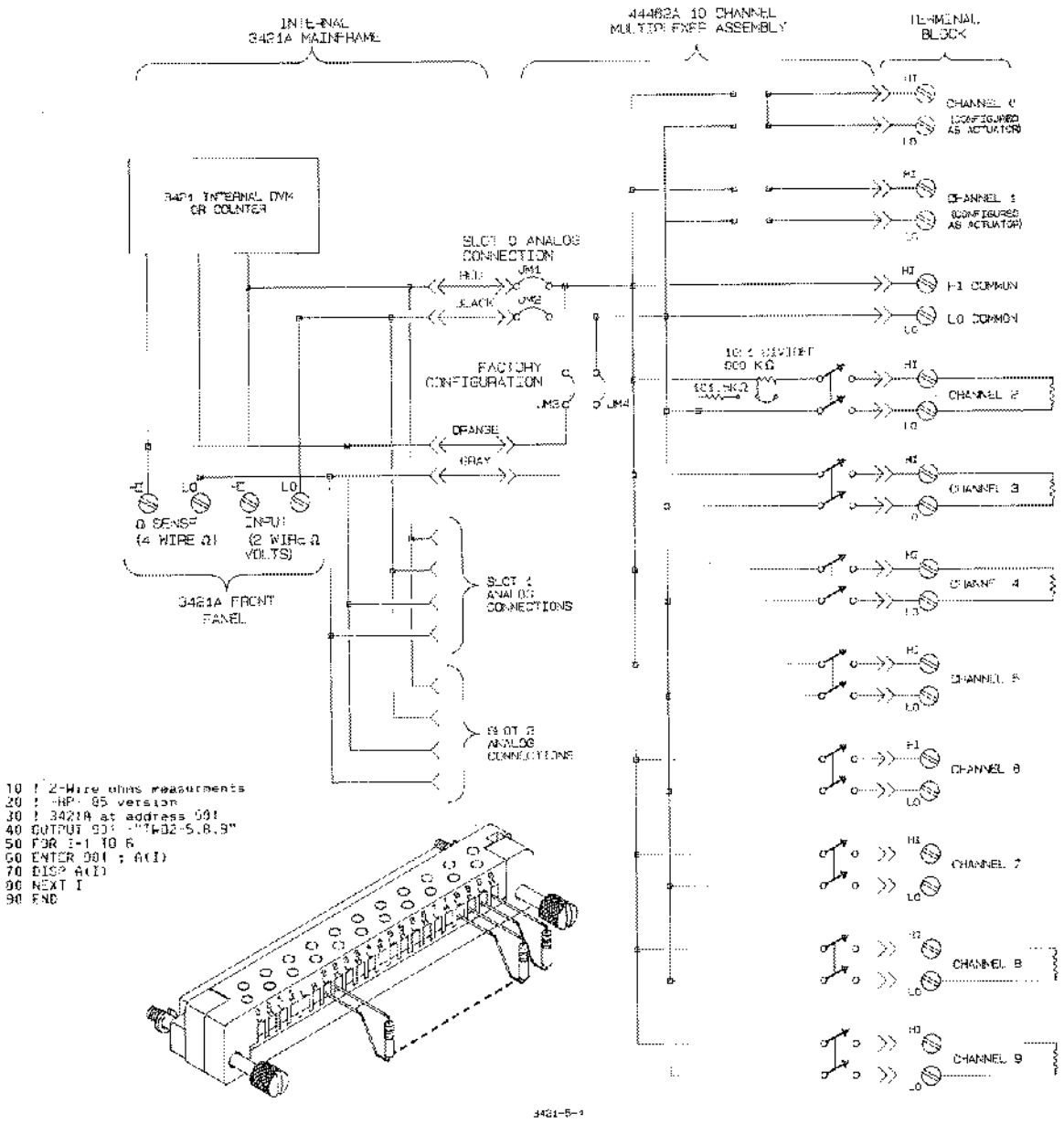


Figure 5-4. 2-Wire Resistance Measurements

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FWO[x,y,...z], 4-Wire Resistance Measurements

4-wire resistance measurements are essential when the highest accuracy is required or where long lead lengths are present. Using the 3421A to make 4-wire measurements necessitates two 44462A relay assemblies. As mentioned previously, the relay assemblies will require a slight modification. Information for the service technician to make this modification can be found in Chapter 8.

The FWO command acts identical to the TWO command except that a 4-wire resistance measurement is made. Ideally, all addresses in the channel list [x,y,...z] should be in the same decade, that is, the same 44462A board. This is because the channels are paired with [x + 10,y − 10,...z + 10]. This is true unless [x,y,...z] are between 20 and 29, in which case they are paired with [x-20,y-20,...z-20].

CAUTION

Anytime a channel is specified with the FWO command, the 3421A will attempt to close the appropriate pair. If either the specified channel or its pair is not on a 44462A multiplexer assembly, an error will be generated but no other action will be taken. If both channels are on 44462A assemblies and are configured as multiplexers, both channels will be closed. Make certain that you know what is connected to both channels, and the configuration (i.e., actuator, etc.) before executing the FWO command.

Figure 5-5 demonstrates a typical 4-Wire Ohms measurement setup. The current source leads are connected to one relay assembly. This assembly must have jumpers JM3 and JM4 removed and JM1 and JM2 installed. A second 44462A assembly is used to connect the 4-Wire Ohms Sense Leads. This assembly must have jumpers JM1 and JM2 removed and JM3 and JM4 installed. The two assemblies must be placed in adjacent slots, i.e., 0 and 1, 1 and 2, or 2 and 0. This is because the 4-wire ohms command, FWO, closes two channels, one on each assembly.

For example, if one assembly is placed in slot 1 and the other assembly in slot 2, the command FWO12 would close channels 12 and 22. With this setup, all channels specified in the FWO channel list must be in the same slot, that is, slot 1.

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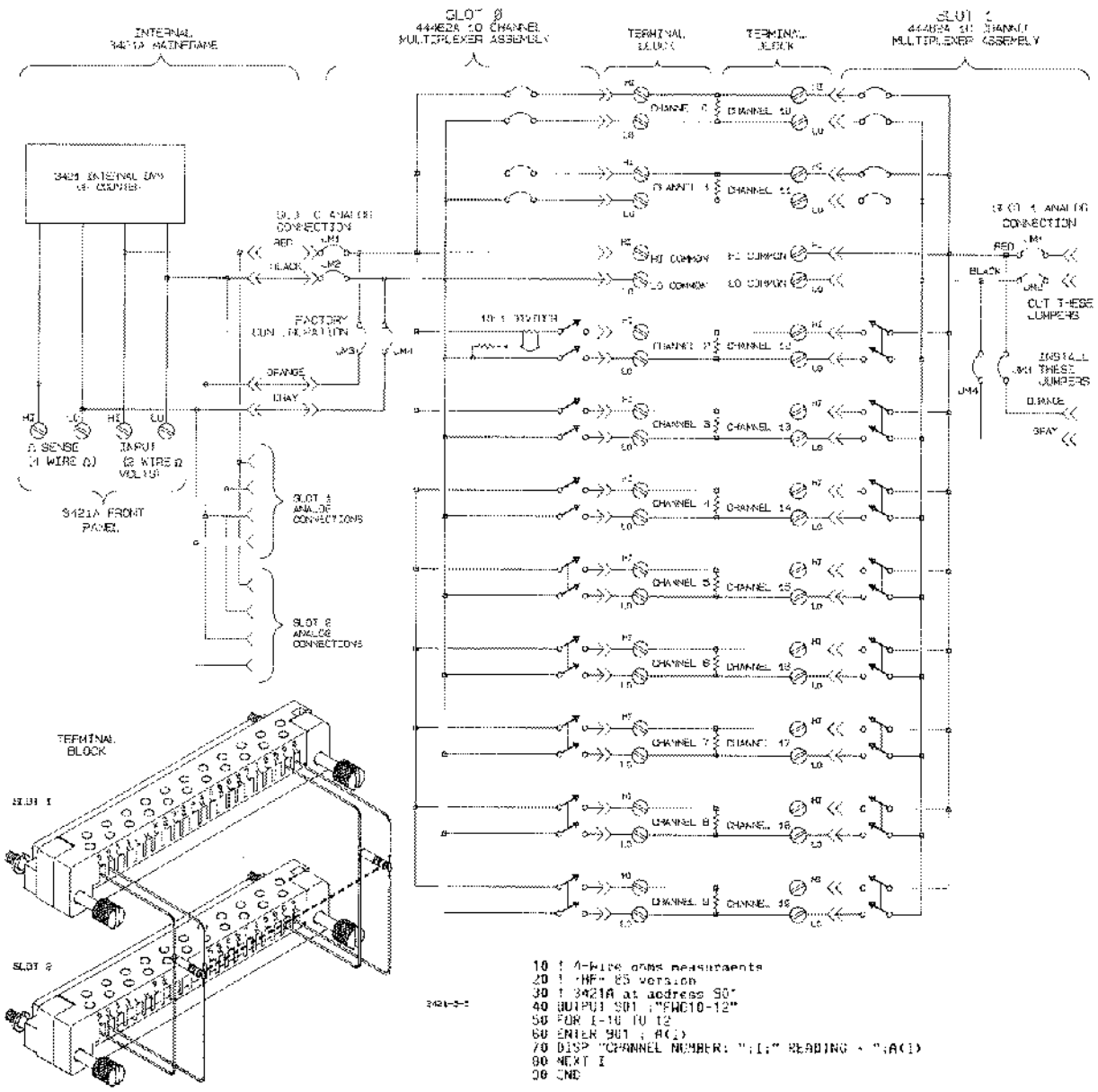


Figure 5-5. 4-Wire Resistance Measurements

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Thermocouple Temperature Measurements

The 44462A assembly is designed for compensated thermocouple temperature measurements. This assembly utilizes an integrated circuit temperature sensor to determine the temperature of the terminal block. In performing a software compensated thermocouple temperature measurement, the following steps must occur:

1. Measure the temperature transducer voltage from the relay assembly and compute the terminal block temperature. This is known as the reference temperature. The Standard REF command will perform this step automatically.

2. Convert the terminal block temperature to a thermocouple reference voltage. The implementation of this step is dependent upon the type of thermocouple being compensated and allows the use of different thermocouple types on the same 44462A assembly.

3. Measure the voltage produced by the thermocouple.

4. Add the reference voltage (computed in step 2) to the voltage produced by the thermocouple to effect icepoint compensation.

5. Convert the sum total voltage (step 4) to a temperature in °C.

Note that if type T thermocouples are used, the 3421A TEM command performs all of these steps automatically and returns the measured temperature. However, if other thermocouple types are used, the 3421A can do steps 1 and 3, but the system computer must perform steps 2, 4 and 5. Examples are provided in both chapters 3 and 4 showing how this can be done and listing the necessary conversion coefficients.

TEM[x,y,...z], REF[x]

The TEM[x,y,...z] command follows the same constraints as the DCV[x,y,...z] command. The REF[x] command is used to measure the temperature of the reference junction (integrated circuit transducer) on the multiplexer assembly where channel 'x' is located. The answer returned is in degrees C. If channel 'x' is not specified, the REF command defaults to a 44462A assembly that has a relay closed. If there are no relays closed, the REF command goes to the 44462A assembly with the lowest slot number. If there are no 44462A assemblies, a syntax error is generated (see Status Byte in chapters 3 and 4) and the error message -8.88888E+8 is sent.

Figure 5-6 pictorially illustrates how 5 type T thermocouples and one DC voltage source are connected to a 44462A assembly. The program associated with the illustration first measures the DC voltage and then the 5 thermocouples. The TEM command, used with type T thermocouples only, automatically measures the reference voltage and the thermocouple voltages and computes the temperatures.

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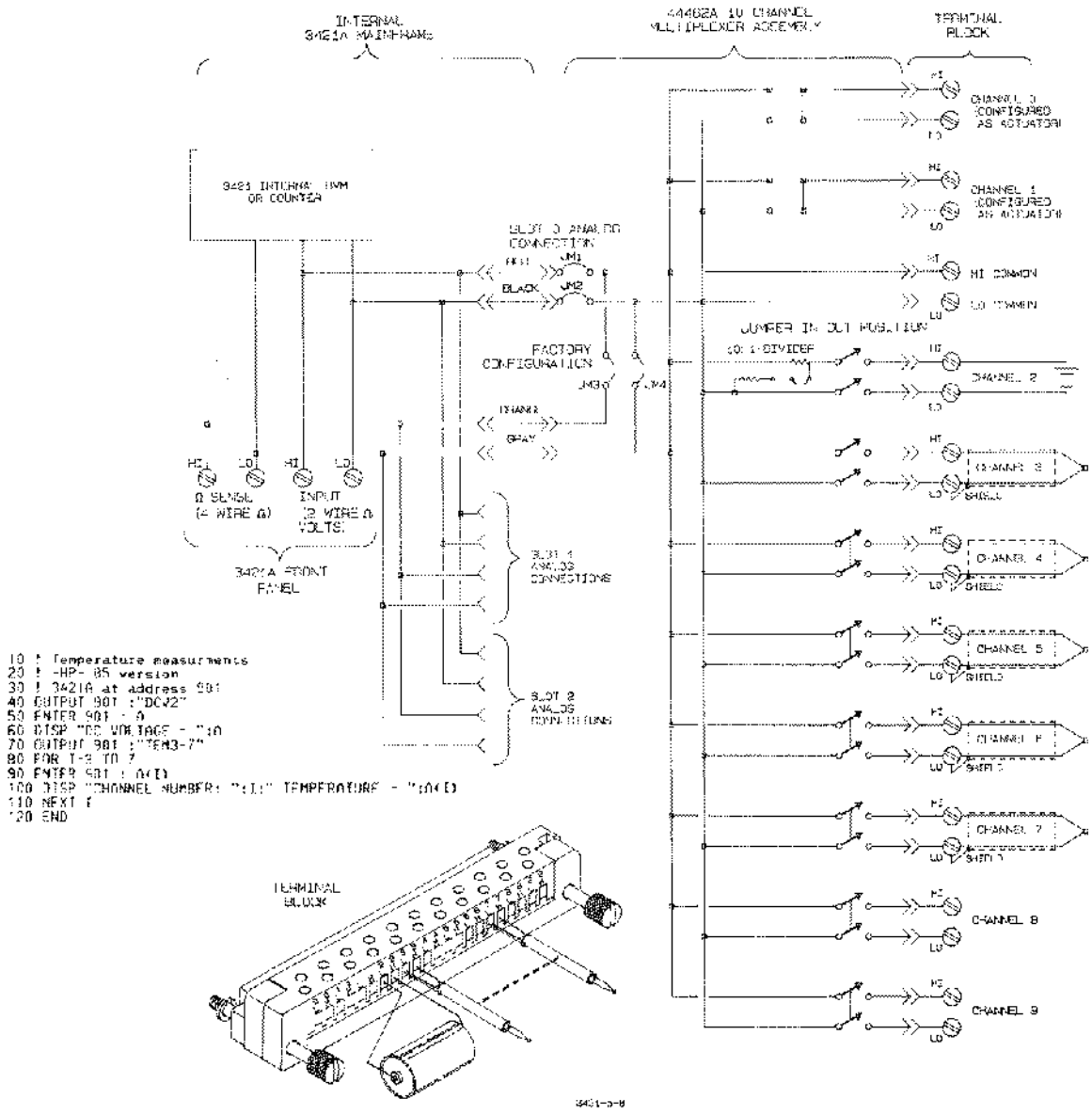


Figure 5-6. Temperature Measurements

For more information on temperature measurements, whether using thermocouples, thermistors, or RTD's, or for thermocouple diagnostics, refer to -hp- Application Note 290, Practical Temperature Measurements.

Counter Functions

The 3421A has the capability of measuring frequencies up to 10 kHz or totalizing events up to a maximum count of 65,535. A typical example for the counter is to measure the frequency of an audio oscillator. The totalize function can be used to count the number of objects passing by on a conveyor belt or count the pulses from a liquid flow meter.

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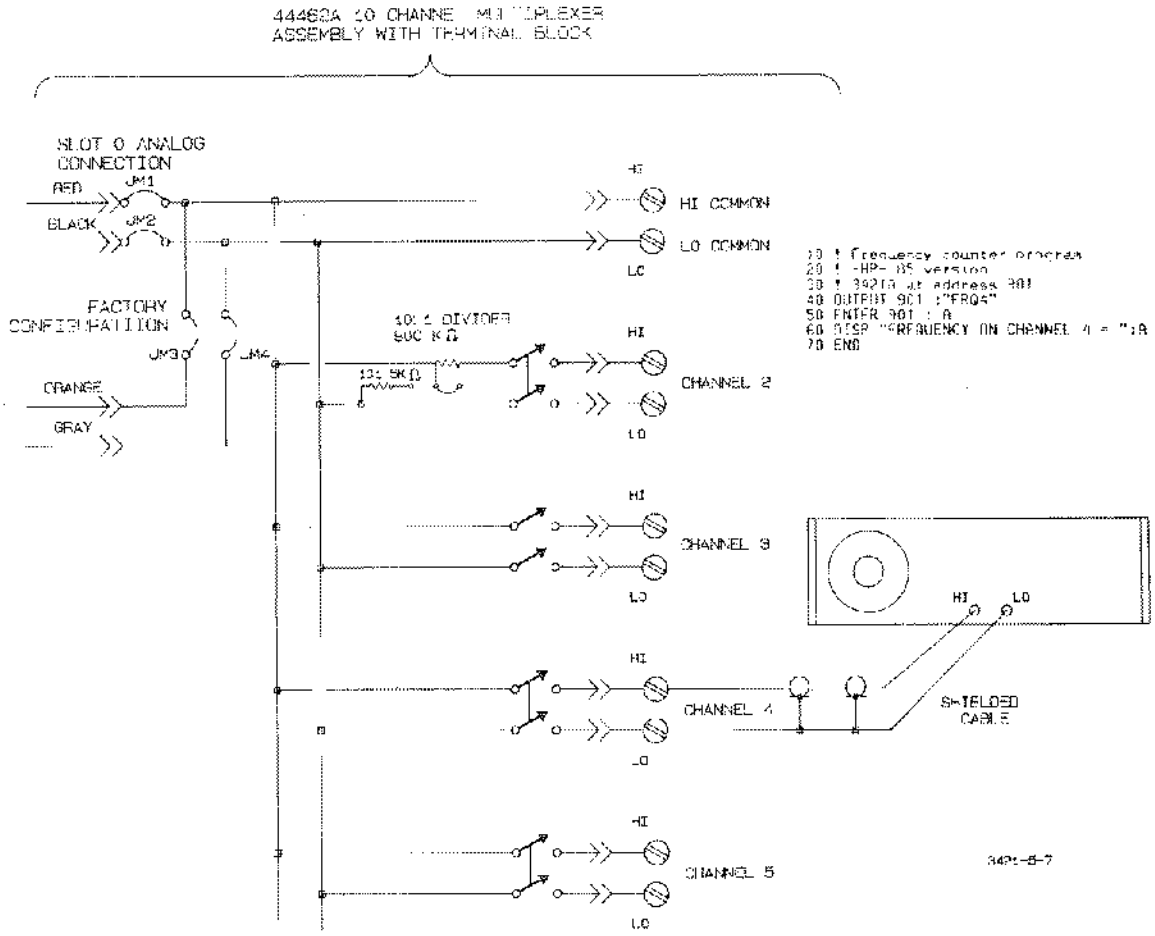


Figure 5-7. Frequency Measurements

FRQ[x,y,...z]

The FRQ[x,y,...z] command sets up the 3421A to the frequency counter mode, 1 second gate time, and 5 ½ digit resolution. If no channel list is sent, the frequency measurement is made from whichever channel is closed. If a channel list is sent, frequency measurements are made and stored from each channel in the sequence specified.

TOT[x]

The totalize command, TOT[x] is used to totalize events occurring on the channel specified by 'x'. TOT clears and starts the totalize counter. If a channel is not specified, TOT totalizes on the currently closed channel. If the channel specified is not a multiplexer channel an error is generated. Note that when the 3421A is addressed to talk, it will output the current subtotal from the counter without interrupting the counter.

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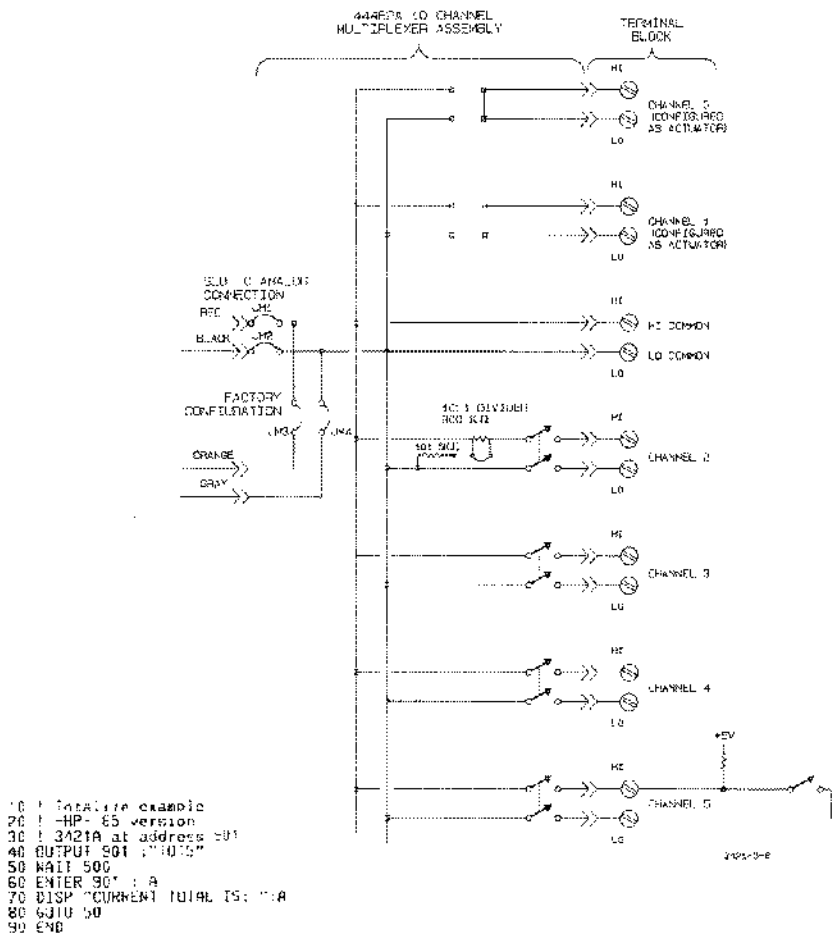


Figure 5-8. Totalizing

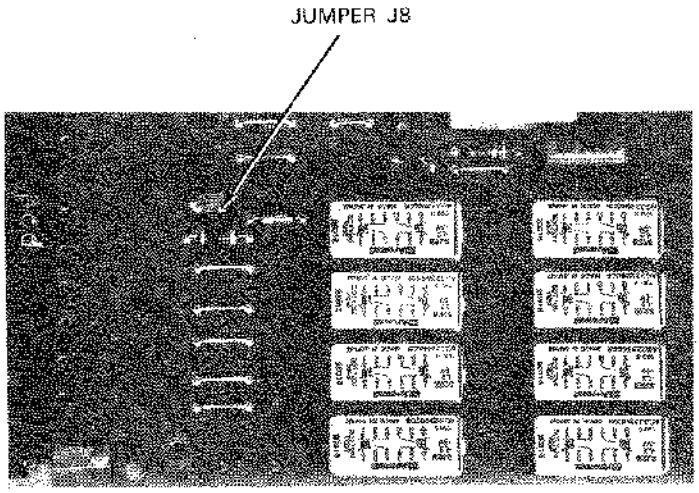
Channel "x" will remain closed until another instruction opens it. Note also that if a trigger command is received while TOT is asserted, the 3421A will abort TOT and begin taking frequency readings (FRQ).

Attenuators

Attenuators are used to reduce an input signal to a useable level. For example, the 3421A AC voltmeter has a maximum range of 30 volts. To measure a 120V power line, an attenuator is used. If a 10:1 attenuator is used, the 120V power line is reduced to 12.0 volts, well within the range of the voltmeter. Precision components should be used to maintain accuracy.

It was mentioned previously that channel 2 on each multiplexer assembly has a built in 10:1 attenuator. This attenuator can be taken out of the circuit (no attenuation) by moving jumper J8 on the assembly to the 'OUT' position. Any voltage measured from channel 2 with the jumper J8 in the 'IN' position must be multiplied by 10 to obtain the correct value.

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Channels 0, 1 and 3 through 7 have provisions for installing your own components (series and/or shunt) for attenuators, etc. Channels 8 and 9 have provisions for installing components in shunt (from HIGH to LOW terminals) with the signal path. Chapter 8 provides information sufficient for the service trained technician to install and reconfigure the option board assembly.

WARNING

Only qualified personnel with a knowledge of electronic circuitry should install and reconfigure the option boards. Installation and configuration information for this option board is provided in Chapter 8.

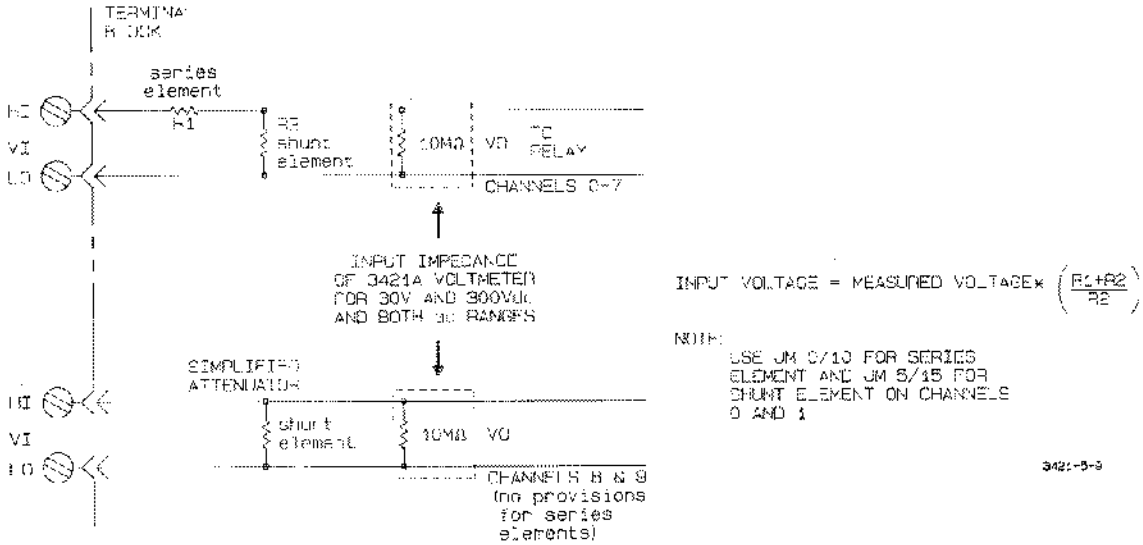


Figure 5-9. Attenuators

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Actuators

Channels 0 and 1, as the assembly is shipped from the factory, are configured as actuators. Each relay can be used to switch 150 VA maximum thus making them ideal for switching power to external devices. Relay contact protection is provided to minimize RFI and extend relay contact life. Two commands that are generally used with the actuators are CLSx and OPN[x].

Figure 5-10 illustrates how one actuator may be used to switch power to sound an alarm. Chapter 8 provides sufficient information for the service trained technician to install and reconfigure the actuators.

WARNING

Only qualified personnel with a knowledge of electronic circuitry should install and reconfigure the option boards. Installation and configuration information for this option board is provided in Chapter 8.

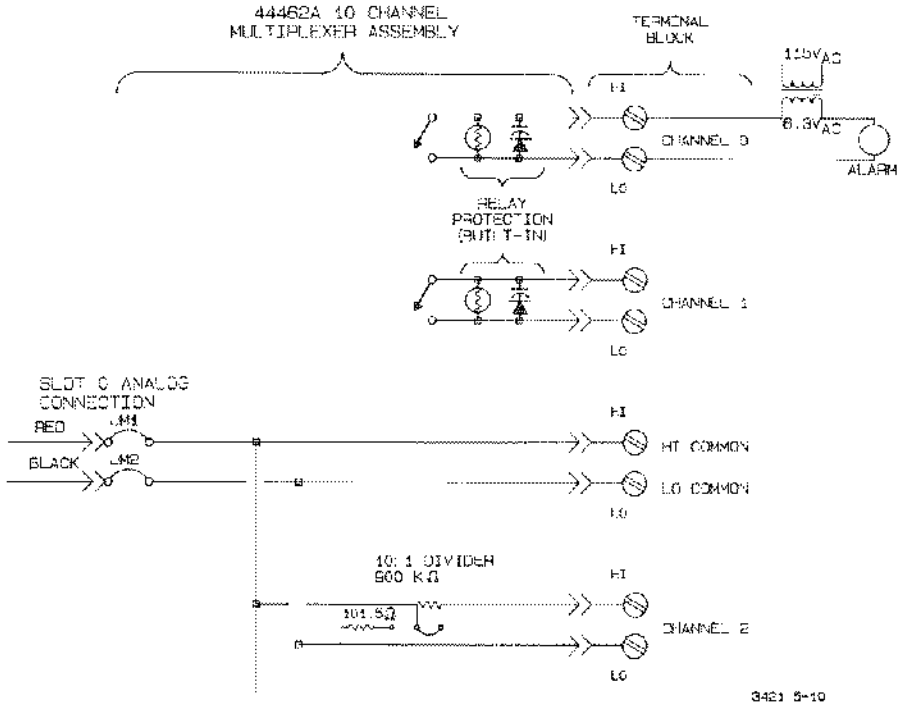


Figure 5-10. Actuator

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Power Down/Power Failure

When using the 3421A in control applications, it is imperative to know what the state of the actuator relay will be in during Power Down or in the event of power failure. When the 3421A receives a Power Down command, the relays will not change state. Moreover, they cannot be changed until the 3421A is powered up. Should the AC power line fail, the 3421A automatically operates from its internal battery, so no change occurs. In the event the battery should fail, still no relays change state.

Please note that this applies only the 44462A actuators. The switches in the 44465A Digital Output port may also be used as actuators. In the event of power down or power failure, all digital output port actuators will assume a high impedance (open) state.

Channel and Advanced Commands

There are several other commands that directly relate to the 44462A 10 channel multiplexer assembly. These commands are provided to further enhance the power and flexibility of the 3421A and its multiplexer option.

CLSx

CLSx is used to close a single relay, whether it is an actuator relay or a multiplexer relay. If the channel specified by "x" does not exist, a syntax error is generated. See Status Byte in Chapter 3. Valid channel numbers for actuators are 0, 1, 10, 11, 20, and 21.

CLPx

The CLPx command is used to close a pair of channels simultaneously. It first opens all multiplexer relays and then closes channels x and x+10 (e.g., CLP12 closes channels 12 and 22). If channel x is between 20 and 29, then channels x and x-20 will be closed (e.g., CLP25 closes channels 25 and 5). If either x or its pair is not a multiplexer channel, then no channels will be opened or closed and a syntax error generated. This command is useful for closing two channels when making 4-wire ohms measurements.

OPN[x]

The OPN[x] command is used to open the relay specified by "x". If "x" is not sent, the OPN command opens all relays. An error is generated if the channel specified by "x" does not exist.

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LSx[,y,...z]

The LSx,[y,...z] command (Load Single multiplexer channels) can be used to load the channel list. The channels are loaded in the order received and the channel list pointer is reset to the first channel. If a T3 or SI1 command is received all multiplexer channels will be opened and the first channel in the list will be closed.

LPx[,y,...z]

LPx,[y,...z] is used to Load Pairs of scanner channels into the channel list. Essentially, this is the same as the LS command except that channels x and x+10, etc., are closed simultaneously. If x is greater than 20, then x and x-20 are closed.

RL

To Read the current channel List, the RL command is used. When the 3421A is addressed to talk, the channel list is sent to the controller in the same sequence that they are assigned. Channel numbers are separated by a Carriage Return, Line Feed. If a place in the list is empty, the place will be marked by "99". For example, if you assign a channel list of 1-7,15,18 and then read it back, the response will be: 1, 2, 3, 4, 5, 6, 7, 15, 18, 99, 99, 99, 99... until all 30 positions in the list are sent.

SI0, SI1

These two commands are called the System Increment commands. SI0 is used to initialize the channel list pointer to the first channel in the list. No channels are opened or closed. The SI1 command, however, is used to increment the channel list. The current channel is opened and the next channel in the list is closed.

DTx

The DT command (Digital Trigger) allows for external triggering of the voltmeter or counter. This feature looks at Digital Input bit at address "x" and when that bit goes LOW, a T3 trigger is executed. T3 turns on reading storage and reads from the channel list. Consider the following example. The channel list is set up using the LS command, the voltmeter is set to DC Volts (F1) and autorange (RA1), etc. When input bit "7" goes low in slot "1" goes low, the voltmeter takes the readings, stores them and then interrupts the computer via Data Ready SRQ. Lines 10 through 30 could be combined into one OUTPUT statement but are separated here to make it easier to follow the program.

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```
10 DIM A(7)
20 OUTPUT 901 ;"LS2-7;F1RA1Z1N4
   " ! SET UP 3421A FOR
       MEASUREMENTS
30 OUTPUT 901 ;"M1" ! SET SRQ
     MASK FOR READING READY
40 OUTPUT 901 ;"DT17" ! SET
     DIGITAL TRIGGER FOR
       CHANNEL 17
50 SEND 7 ; UNL ! THIS LINE
     NEEDED FOR HP-IB ONLY
60 ON INTR 9 GOSUB 1000 ! WHERE
     TO GO WHEN INTERRUPTED
70 ! PUT MAIN BODY OF PROGRAM
     HERE
900 GOTO 70
910 END
1000 ! START OF INTERRUPT
     SUBROUTINE
1010 FOR I=2 TO 7
1020 ENTER 901 ; A(I)
1030 DISP A(I)
1040 NEXT I
1050 RETURN
```

UCx

The UCx command is used to UNCONDITIONALLY Close a channel or set a digital bit (see chapter 6). No channels are opened when the UC command is executed.

NOTE

Use extreme caution when using this command. It is possible to have two or more channels closed simultaneously with this command. Damage to the instrument or to external transducers or other instrumentation may result.

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Application Examples

The sample program in the DT command illustrates that any of the voltmeter Advanced Commands can be used with the 44462A assembly. This of course applies also to the counter Advanced Commands. The following Application Examples are designed to show you how to enhance the measurement capabilities of the 3421A.

Burst Measurements

The following program shows how the 3421A can take a burst of 30 readings from a selected channel, in this case 5. This burst will take less than 1 second to complete.

Line 20 sets the 3421A to hold measurements but enable the channel list scanner (T0), loads the entire channel list with channel 5 (LS5-5), DC volts (F1), autozero off (Z0), and 3½ digits of display (N3). When the 3421A is triggered (T3), it will take 30 readings from channel 5 and store them. The readings are read back and displayed in lines 40 through 80.

```
10 ! Burst measurements
20 DIM A(30)
30 OUTPUT 901 ;"T0L35-5;F1Z0N3T
   3"
40 FOR I=1 TO 30
50 ENTER 901 ; A(I)
60 DISP "READING # ";I;"READING
   = ";A(I)
70 NEXT I
80 END
```

Single Ended Measurements

Single ended measurements allow you to expand the multiplexing capability of your 3421A to a maximum of 56 inputs. Effectively, a single ended configuration changes a single channel into two channels. When using this method, one of the installed 44462A Multiplexer Assemblies should have channels 0 and 1 configured as actuators. The actuators are used to switch the HI and LO relays of the remaining channels to the Ω/V HI front panel terminal of the 3421A. Input Common is shared by all inputs, is not switched, and is connected to the Ω/V LO front panel terminal. A schematic of a single ended configuration is shown in Figure 5-11. In this example, 44462A Multiplexer Assemblies occupy slot 0 and slot 1. The slot 0 assembly has channels 0 and 1 configured as actuators for switching the remaining channels.

The 44462A Multiplexer Assembly that is configured with the two actuators for switching the inputs can provide 16 single ended channels; other installed Multiplexer Assemblies can provide 20 single ended channels each.

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There are four important rules pertaining to single ended measurements that must be followed.

CAUTION

Failure to Comply with the following four rules could result in equipment damage.

Make certain that only one actuator channel is closed at any given time. If the two actuator channels are both closed at the same time, damage to the 3421A or the voltage source being measured could result.

Any 44462A Multiplexer Assembly that is configured for single ended measurements can only be used for single ended measurements. For example, suppose you have two 44462A Multiplexer Assemblies installed but need 22 channel capability. By using the single ended method, 36 channels will be available (16 + 20) but 14 will remain unused.

All inputs to be measured must be referenced to Input Common which is connected to the 3421A Ω/V LO front panel terminal. This is the unswitched voltmeter input. Heavy gauge wire is recommended for this Input Common connection to minimize common mode voltages. Use extreme caution when making floating measurements.

AC Voltages that are input to the 3421A internal voltmeter are limited to 30V RMS. Higher voltage must be attenuated to a maximum of 30V RMS by external attenuation. Using the built-in attenuator on channel 2 of any 44462A Multiplexer Assembly configured for single ended measurements is not permitted.

If actuator channels 0 and 1 have been previously used in a high current application, it would be a good idea to perform the performance verification procedure before using them in a single ended measurement application (see Section IV of the 10 Channel Multiplexer Service Manual). A high current application could cause corrosion of the relay contacts which in turn could degrade input signal quality.

Once the single ended configuration is made, channel selection is straight forward. Channel lists may be specified the same as with any other type of measurement (eg., DCV2-19). When you specify an input, the input that will be read will depend upon which actuator is closed. In other words, the actuator channels are used to select either the HI or LO relay of the channel selected when the DCV command is executed. For example, if your configuration is like that shown in Figure 5-11 and DCV2 is executed with actuator 0 closed, the input will be the one connected to the channel 2 LO relay; if actuator 1 is closed, the input will be the one connected to the channel 2 HI relay.

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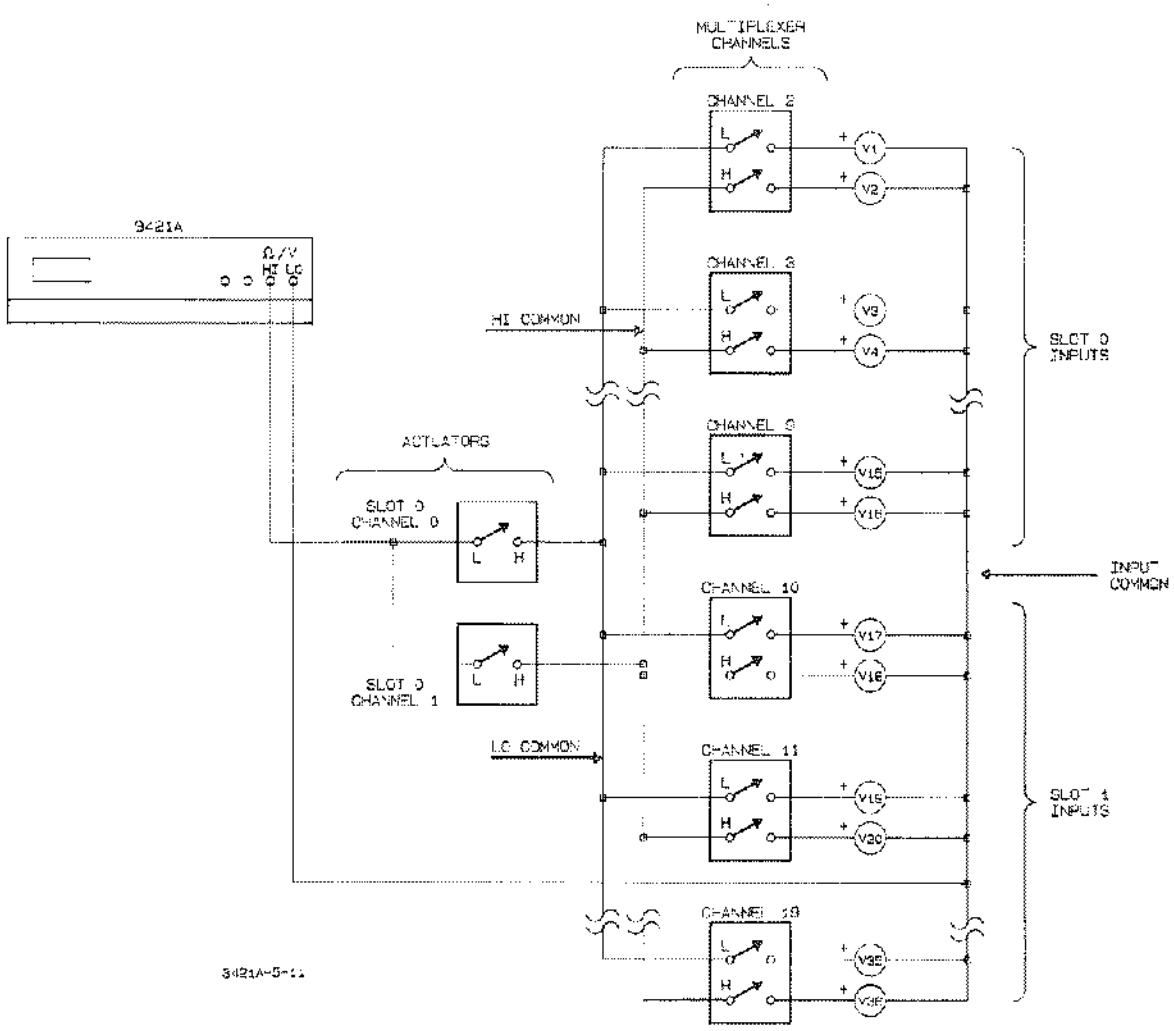


Figure 5-11. Single Ended Measurements

The following recommended procedure explains how to configure three 44462A Multiplexer Assemblies to permit up to 56 single ended channels to be measured. The procedure can be easily modified if you have less than three Multiplexer Assemblies to be configured.

Step 1. Remove JM1, JM2, JM3, and JM4 from each Multiplexer Assembly to be used for single ended measurements. JM1 and JM2 are the only jumpers installed at the factory. Removing these jumpers opens the path between the Multiplexer Assemblies and the 3421A internal voltmeter. The voltmeter connections will be made to the 3421A front panel in a later step.

Step 2. Place J8 on each Multiplexer Assembly to be used to the "OUT" position, if it is not in that position already. This removes the 10:1 attenuator on channel 2.

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Step 3. On the Multiplexer Assembly to occupy slot 0, place J6 and J7 in the "1" position. This may or may not be the factory configuration, depending upon how the Multiplexer Assembly was ordered. The 3421A logic circuitry uses these setting to determine that channels 0 and 1 on this assembly are actuators and all other channels are multiplexers.

Step 4. On the Multiplexer Assembly to occupy slot 0, make sure JM08/18, JM09/19, and JM0/10 are in place and that JM05/15 and JM06/16 have been removed. This may or may not be the factory configuration, depending upon how the Multiplexer Assembly was ordered. This will configure channels 0 and 1 as actuators.

Step 5. On the Multiplexer Assemblies to occupy slots 1 and 2, place J6 and J7 in the "0" position. This may or may not be the factory configuration, depending upon how the Multiplexer Assembly was ordered. The 3421A logic circuitry uses these settings to determine that all channels on these assemblies are multiplexers.

Step 6. This step has two parts and will configure the assemblies in slots 1 and 2 so that all channels are configured as multiplexers. This configuration may or may not have already been performed, depending upon how your Multiplexer Assembly was ordered.

a. On the assemblies in slots 1 and 2, solder jumpers at JM0/10, JM05/15, and JM06/16.

b. On the assemblies in slots 1 and 2, remove jumpers at JM08/18 and JM09/19.

Step 7. Refer to Figure 5-12 and configure the terminal block edge connectors as follows:

a. On the slot 0 terminal block edge connector make the following connections:

HI Common to H1
LO Common to H0
L1 to L0
L0 to the 3421A Ω/V HI Front Panel Terminal

b. Interconnect the terminal block edge connectors of all Multiplexer Assemblies to be used for single ended measurements as follows:

HI Common between all terminal block edge connectors
LO Common between all terminal block edge connectors

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Step 8. Connect the "+" side of the inputs to be read to the various points on the terminal block edge connectors. The "+" does not necessarily mean a positive voltage, but rather indicates the "hot" side of the input. Input V1 connects to L2 on the slot 0 terminal block; input V2 connects to H2 on the slot 0 terminal block, etc..

Step 9. Connect the common side of all inputs together and then connect this input common to the 3421A Ω/V LO front panel terminal.

An HP-85 program example for the single ended configuration just explained is provided.

```
10  ! Single ended measurements
        example
20  ! -HP- 85 version
30  ! 3421A at address 901
40  DIM A(19)
50  OUTPUT 901 ;"OPN"
60  ! Measure 'HI' side of
        relays (even sources)
70  DISP "HI's" @ DISP
80  OUTPUT 901 ;"CLO1" ! Close
        Actuator #1
90  OUTPUT 901 ;"DCV2-19"
100 FOR I=2 TO 19
110 ENTER 901 ; A(I)
120 DISP "CHANNEL NUMBER: ";I;"
    READING = ";A(I)
130 NEXT I
140 ! Measure 'LO' side of
        relays (odd sources)
150 DISP "LO's" @ DISP
160 OUTPUT 901 ;"OPN1" ! Open
        Actuator #1
170 OUTPUT 901 ;"CLS0" ! Close
        Actuator #0
180 OUTPUT 901 ;"DCV2-19"
190 FOR I=2 TO 19
200 ENTER 901 ; A(I)
210 DISP "CHANNEL NUMBER: ";I;"R
    EADING ";A(I)
220 NEXT I
230 END
```

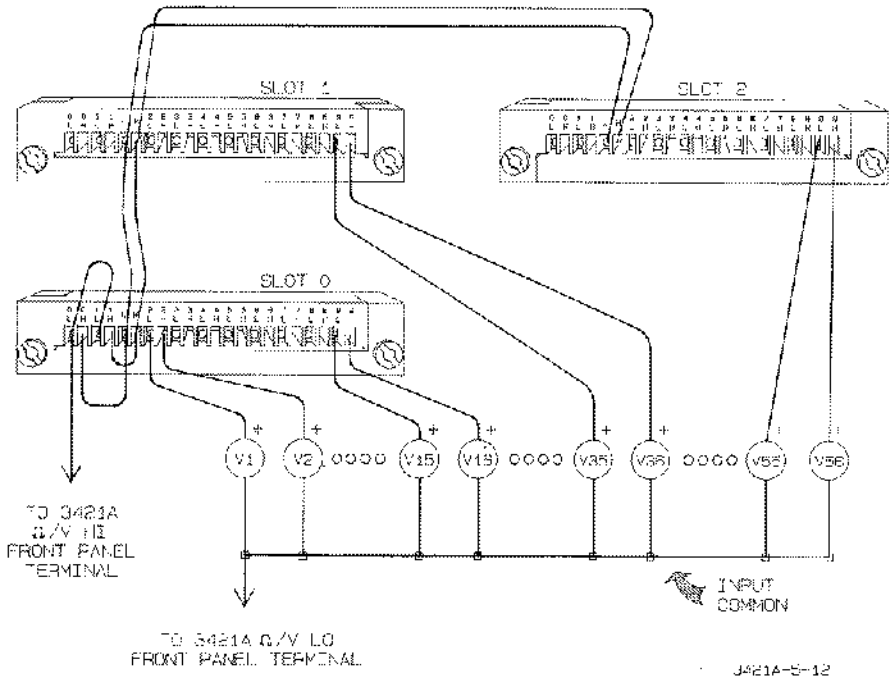


Figure 5-12. Configuration for Single Ended Measurements

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Shielding and Noise Rejection

Inaccuracies caused by radiated and/or "Common Mode Noise" are common problems with Data Acquisition Systems. These problems are especially pronounced when the signal being measured is quite small, such as with thermocouples. The 3421A, however, helps to eliminate many of these types of problems. For example, the 3421A internal voltmeter uses a method of integration for analog to digital conversion. Integration is a process where noise is averaged over a full power line cycle. Thus, power line frequency related noise and its harmonics are virtually eliminated.

The purpose of this section is to demonstrate additional ways of reducing the effects of noise on low signal level measurements.

Consider the following example. Several thermocouples are attached to an automobile engine to monitor engine heating. The engine is located several hundred feet from the Data Acquisition system. To further complicate matters, the thermocouple wires have been pulled through the same conduit as a 220V AC power line. The capacitance between the power lines and the thermocouple wires will create an AC noise on the thermocouple wires. Shielding the thermocouple wires and connecting the shield to the LO terminal on the 3421A serves to shunt the noise away from the voltmeter.

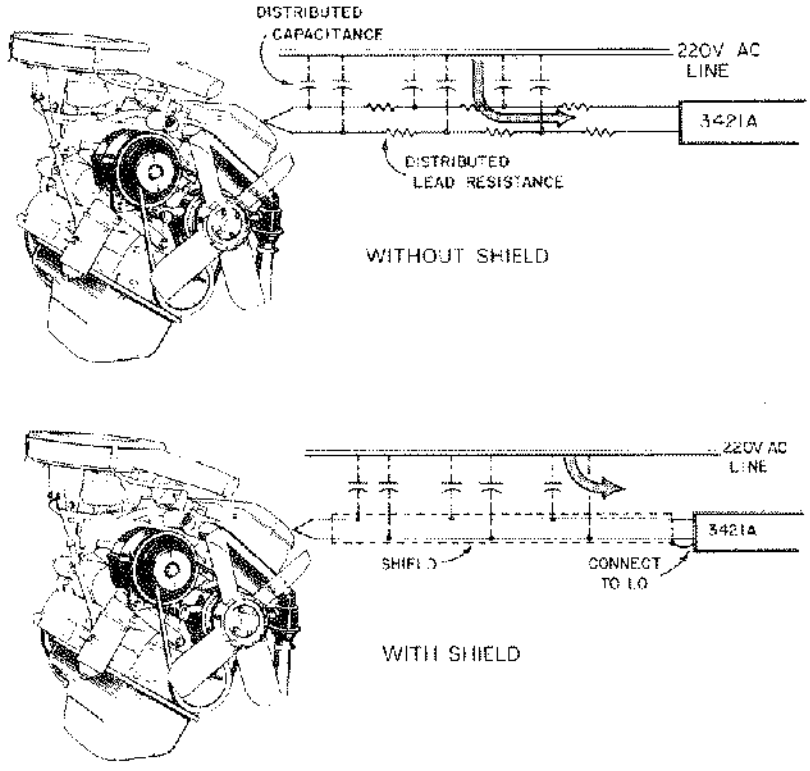


Figure 5-13. Shielding

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A second source of noise, called Common Mode Noise or Common Mode Voltage (CMV), occurs if there is a voltage difference between the engine ground and the System ground. If this common mode voltage is very large, say 100VAC, potential damage to the 3421A could result. To illustrate, Figure 5-14 shows two thermocouples attached to the base of a light bulb.

Assume, for the moment, that channel 1 closed when the CMV was at its top peak. This means the voltmeter LO terminal would be at voltage V1, approximately +141 volts. When channel 1 is opened the LO terminal remains at that voltage due to the stray capacitance. Now if channel 2 is closed when the CMV was at its bottom peak, the LO terminal would immediately drop to −141 volts. This is an instantaneous drop of 282 volts and could conceivably damage the 3421A.

To eliminate this problem, dedicate one channel to a good earth ground, say for example channel 0. Now, between each measurement, close channel 0. This brings the LO terminal to 0 volts which is a maximum step of only 141 volts which is quite safe for the 3421A.

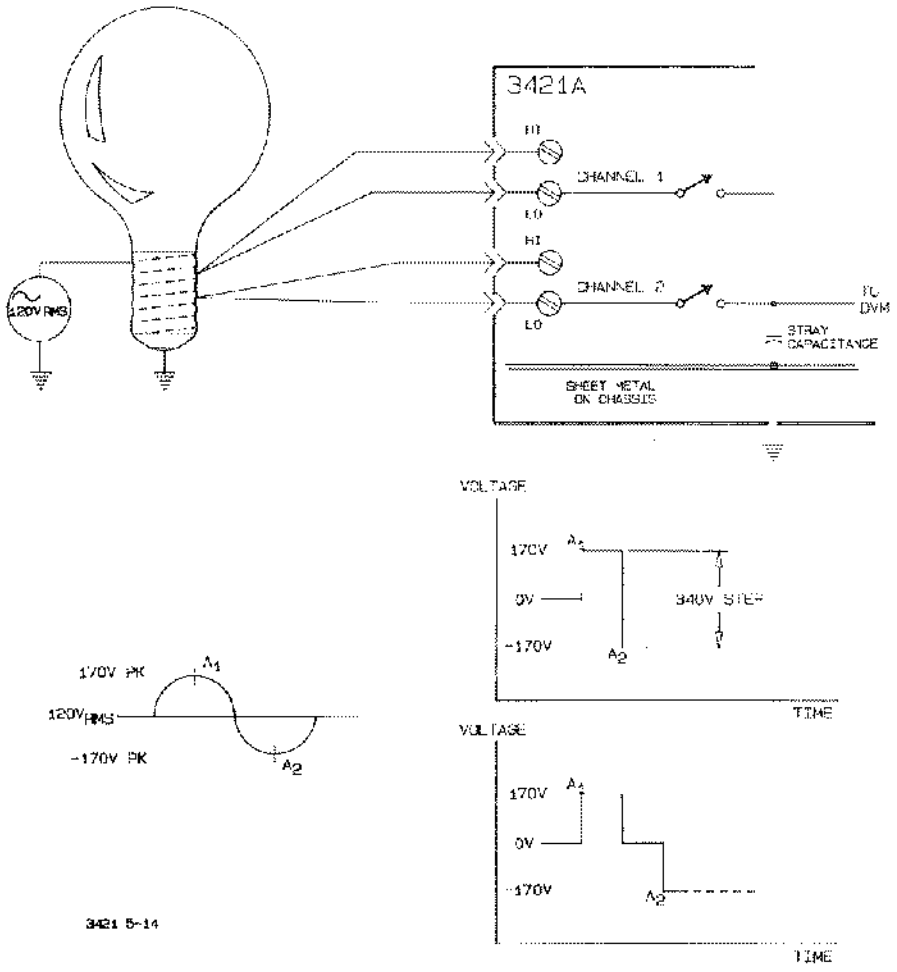


Figure 5-14. Common Mode Noise

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4-20 mA Current Loop

The 44462A assembly is capable of sensing the current in a 4-20 mA industrial current loop. A resistor must be placed in shunt with the the current path and the 3421A voltmeter used to monitor the resultant voltage drop. A suitable resistor is 50 Ohms, .1%, .5 watts (such as -hp- part number 0699-0064). The formula for converting the measured voltage drop to loop current is:

$$\text{Loop Current} = \frac{\text{Measured Voltage}}{\text{Shunt Resistance (50 Ohms)}}$$

Thus, the 50 ohm resistor converts the 4-20 mA signal to 0.2-1 volt signal.

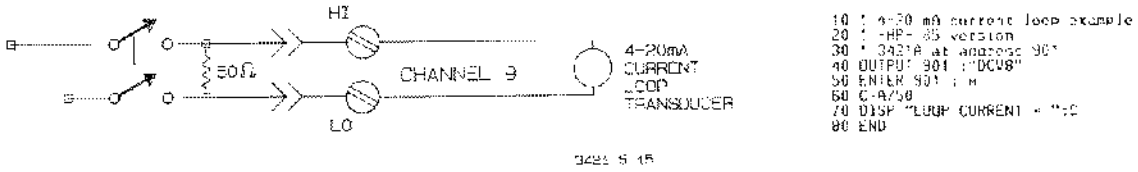


Figure 5-15. 4-20 mA Current Loop

Specifications

The following specifications are the critical specifications that must be considered in all applications. Expanded specifications may be found in chapter 7 of this manual.

Voltage (multiplexer): 300VDC 250VAC RMS 150VA Maximum
(actuator): 300VDC 250VAC RMS 2A Maximum

Contact Resistance: < 1.4 Ohms

Thermal Offset (multiplexer): < 3μV

All relays break-before-make

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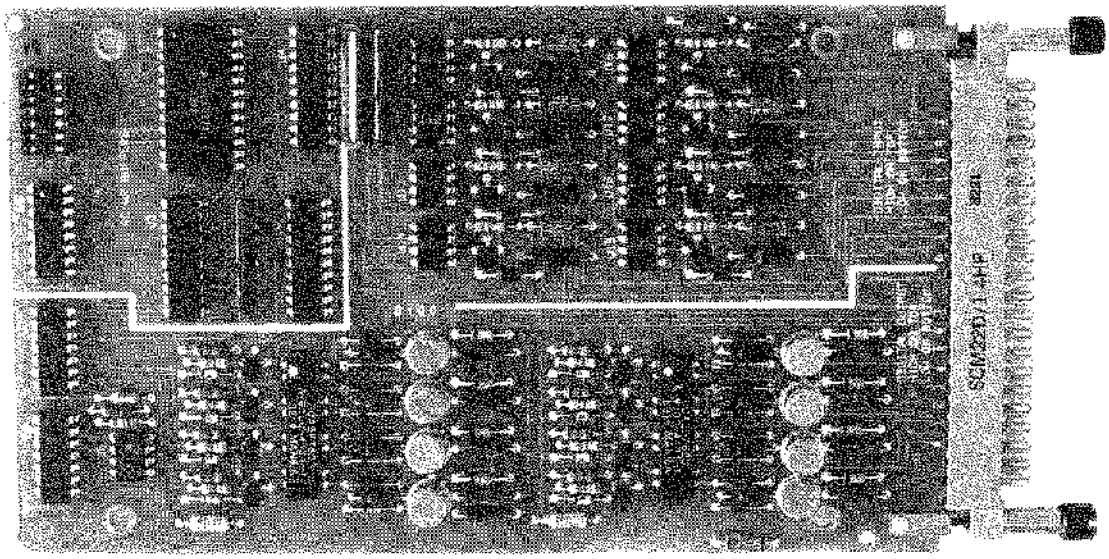
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Chapter 6
44465A
8 Bit Digital I/O Option
(Option 040)

Introduction

The 44465A Digital I/O assembly gives you the capability of monitoring the closure of position switches and closing relays. In addition, you can use the assembly to trigger the internal voltmeter when an event occurs. This chapter gives the operating instructions for the 44465A Digital I/O option. Here you will learn how the option can be used in a wide variety of applications. This assembly can be used almost anywhere you need on/off, present/absent type of information and control.

Several program examples are included to enhance your understanding and provide you practice in using the commands. All computer programs in this chapter are written in BASIC language such as used by the -hp- 85 computer. Feel free to experiment with the programs and alter them to meet your individual needs.



Each 44465A Digital I/O card provides one 8-bit input port and one 8-bit output port. Each bit is electrically isolated from the rest. Typical uses for the input port include limit and position switch monitoring and communicating with digital logic circuits. The output port can be used in low voltage switching applications. Critical specifications for the card are located near the end of this chapter.

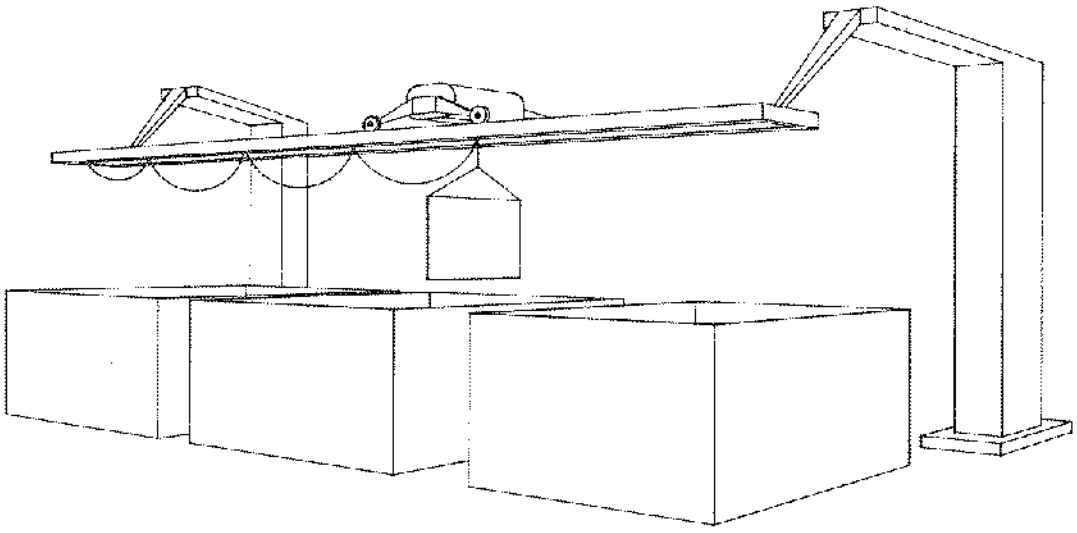
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CAUTION

Only qualified personnel with a knowledge of electronic circuitry should install or reconfigure the option boards. Installation and configuration information for this option board is provided in Chapter 8.

Input Port Overview

Many monitoring capabilities are provided at the input port. Typical uses for the input port involve monitoring switches or valves to determine if they are open or closed. This can best be described with an illustration. Imagine for a moment an overhead trolley. As the trolley moves along its track it must stop at several stations to perform some task. Position switches are used at each station to signal the controller to stop the trolly motor. Each position switch is sensed by an individual bit in the digital input port. The reason it is called a digital port is because it acknowledges two different states; i.e, either the switch is open or it is closed.



The 8-bit input port is optically coupled to provide maximum isolation and prevent noise and ground loops. A wide range of input supply voltages (2.4 to 24 Vdc) coupled with a maximum current of 25 mA means that the input port can be used in a wide variety of applications. Let's take a look at the command set before looking at specific examples using the port.

Standard Commands

The two STANDARD commands used most often with the input port are REDi (REaD slot i) and BITx. REDi allows you to look at the entire 8-bits (each "bit" represents

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one switch) from the slot specified by "i". BITx, however, permits you to select individual bits to look at. In the following discussion the words "set" and "clear" will be used. Set means that a condition is true; e.g., a switch is closed, a logic "1" condition, etc. Clear means just the opposite; i.e., the switch is open, or a logic "0" condition. So you won't be confused by these terms, several examples are provided in this section to illustrate exactly what they mean.

REDi

The REDi command reads all digital input bits associated with slot "i" and responds with a decimal number between 0 and 255. This decimal number corresponds to the sum of the values of the individual bits that were "set". For example, if you have a Digital I/O card in slot 1 and bits 0,2 3, 5, and 7 are "set" (all others are cleared), the value 173 would be returned. Refer to the chart below.

Bit Number	7	6	5	4	3	2	1	0
Bit value if set	2^7 = 128	2^6 = 64	2^5 = 32	2^4 = 16	2^3 = 8	2^2 = 4	2^1 = 2	2^0 = 1
Example: word	1	0	1	0	1	1	0	1
Decimal Value =	128 +	0 +	32 +	0 +	8 +	4 +	0 +	1 = 173

Bit Value Chart

The following is a program to assist you in decoding the decimal number and determining which bits are set. Line 10 sends the REDi command for slot 1. This line should be changed to reflect the slot that your 44465A card is in. Line 20 is used to enter the decimal value and the rest of the program decodes it and prints the "set" bits.

```
10 OUTPUT 901 ;"RED1"
20 ENTER 901 ; A
30 IF A=0 THEN DISP "NO BITS SET"
40 IF A<128 THEN 60
50 A=A-128 @ DISP "BIT 7 SET"
60 IF A<64 THEN 80
70 A=A-64 @ DISP "BIT 6 SET"
80 IF A<32 THEN 100
90 A=A-32 @ DISP "BIT 5 SET"
100 IF A<16 THEN 120
110 A=A-16 @ DISP "BIT 4 SET"
120 IF A<8 THEN 140
130 A=A-8 @ DISP "BIT 3 SET"
140 IF A<4 THEN 160
150 A=A-4 @ DISP "BIT 2 SET"
160 IF A<2 THEN 180
170 A=A-2 @ DISP "BIT 1 SET"
180 IF A<1 THEN 200
190 A=A-1 @ DISP "BIT 0 SET"
200 END
```


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BITx

The BITx command allows you to look at individual bits. The following table shows the addressing scheme for individual bits for 44465A cards in each of the three slots of the 3421A. Notice that bit addresses 08, 09, 18, 19, 28, and 29 are not allowed. The 3421A sends a value +1.000E+0 if the bit is set and +0.000E+0 if the bit is clear.

	Bit Address if card in Slot #		
Bit#	Slot 0	Slot 1	Slot 2
0	0	10	20
1	1	11	21
2	2	12	22
3	3	13	23
4	4	14	24
5	5	15	25
6	6	16	26
7	7	17	27

Bit Value Address Chart

Look again at the example given in the bit value chart earlier. If you execute a "BIT17" (for bit 7 in slot 1) followed by an ENTER statement, the calculator will show a value of 1. The following program shows how this can be done. If you execute a "BIT12" (bit 2 in slot 1), the calculator will return with 0 because the bit is clear.

```
10 OUTPUT 901 ;"BIT17"
20 ENTER 901 : A
30 DISP A
40 END
```

BIT can also be used with a channel list, e.g., BIT17,15,13,11,10. The following program shows how this can be done.

```
10 OUTPUT 901 ;"BIT17,15,13,11,10"
20 ENTER 901 ; A,B,C,D,E
30 DISP A,B,C,D,E
40 END
```

The command BIT0-27 sets the bit list (also called channel) to read all input port bits in the 3421A

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Advanced Commands

The advanced instruction set provides added capabilities for the input port. The three commands in this group are; MHa, MLa, MNi. These three may be used to cause an interrupt (SRQ) to signal the controller. The MNi command uses two other commands, XR[abc] and AN[abc], to specify the parameters that will cause the interrupt.

MHx

The MHx (Monitor High) command monitors the bit specified by "x". Refer to the bit value address chart shown earlier to determine the value of "x". When bit "x" becomes set, the EVENT OCCURRED bit in the Status Register (bit 3, see Chapter 3, SPOLL) likewise becomes set. If the appropriate SRQ mask bit were set, an interrupt (SRQ) is generated to flag the controller. Refer to chapter 3 under the topic of SPOLL for more information on SRQ and the Status Register. When the 3421A is addressed to talk it will output the a decimal number equal to the sum of the values of the bits that were set at the time of the interrupt (similar to a REDi command).

NOTE

If the 3421A receives another command after the the MHx, MLx or MNi command, the monitor function will be turned off.

The proper way of sending the monitor commands to the 3421A is to eliminate the final end-of-line sequence. With the -hp- 85 this is done with the format:

OUTPUT 901 USING "#,K";"MHx;" (or MLx,MNi)

Note the use of the semicolon terminator after MHx. A colon (:) could have been used instead.

MLx

The MLx (Monitor Low) performs the same way as MHx except "Event Occurred" means the specified bit became cleared.

Example

Let's look at an example of this. Assume that you have a 44465A card in slot 2 of your 3421A. You want to monitor bit 1 and when it becomes set, e.g., from a switch closure, you want to print a message. The following program shows how this can be done.

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```
10 ! Digital monitor program
20 ! -HP- 85  version
30 ! 3421A at address 901
40 OUTPUT 901 ;"M8"
50 OUTPUT 901 ;"MH21"
60 ON INTR 9 GOTO 1000
70 ENABLE INTR 9;8
80 ! BODY OF PROGRAM
980 GOTO 80
990 END
1000 STATUS 9,1 ; A
1010 P=SPOLL(901)
1020 IF BIT(P,3) THEN DISP
"DIGITAL INTERRUPT"
1030 END
```

Line	Description
40	Sets up the SRQ mask for event occurred. See Chapter 3.
50	Sets the Monitor High command for bit 1 in slot 2.
55	The SEND 7;UNL command is used only with the HP-IB option. It allows the 3421A to send the SRQ interrupt to the computer.
60	Instructs the computer where to go (line 1000) when an interrupt (SRQ) occurs.
70	ENABLE INTR 9;8 enables the -hp- 85 to respond to the interrupt.
80-990	These lines form the body of the program. They could be replaced by other program statements. The program will continue to run until an interrupt occurs.
1000	Line 1000 is the beginning of the interrupt subroutine. The STATUS command reads and clears the -hp- 85 so that it can respond to future interrupts.
1010	SPOLL places the value of the 3421A Status Register into variable P. It also clears the 3421A Status Register.
1020	Bit 3 of Status Byte (P) is checked to make sure that it is a "1". If it is, then the interrupt was caused by the digital I/O board and the message is displayed. If the bit is a "0", something else caused the interrupt.

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MNi (AN[abc], XR[abc])

The MNi command allows you to specify an entire word (8-bits) to cause an interrupt. MNi uses the XR[abc], AN[abc] commands to extract only the bits you want to look at. XR[abc] is called an Exclusive Or mask. It allows you to specify which bits are to be set to cause the interrupt. The AND mask is set up by the AN[abc] command and allows you to specify which bits you want to monitor. In the discussion to follow, it will help to remember these two points:

1. The XR command determines which bits are to be set to cause the interrupt.

2. The AN command determines which bits you want to look at.

The MNi command reads the input bits from the card in slot i, performs a logical Exclusive-OR with the XOR mask, takes the result and performs a logical AND with the AND mask. If the final result equals 0, the EVENT OCCURRED bit in the Status Register (bit 3) will be set. If the SRQ Mask is set for bit 3, an SRQ interrupt will be generated.

XR[abc]

The XR[abc] command sets the logical Exclusive-OR mask for the MN command. The value [abc] represents a decimal number from 0 to 255. Refer to the bit value chart shown earlier in this chapter. The Exclusive OR function performed by the MN command is done on a bit-by-bit basis. The following Truth Table and example show how the XR mask works.

Logical XOR Truth Table

Input Bit	Mask Bit	XOR Result	Example
0	0	0	1 0 1 0 1 1 0 0 - XR mask = 172
0	1	1	0 1 1 1 0 0 1 0 - Input Bits
1	0	1	- - - - - - - -
1	1	0	1 1 0 1 1 1 1 0 - Logical XOR Result

When you are sending a mask number, whether XR or AN, to the 3421A, it is not always necessary to send all three digits [abc]. Leading zeros are automatically inserted. In other words, XR5 is the same as XR005. If no number is received by the 3421A, the mask is set to all 0's.

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AN[abc]

The AN[abc] command sets the AND mask. The value [abc] represents a decimal number between 0 and 255. Refer to the bit value chart given earlier in this chapter. The AND performed by the MN command is done on a bit by bit basis. For example, sending AN173 would represent a binary AND mask of 10101101 ($2^7 + 2^5 + 2^3 + 2^2 + 2^0 = 173$). Suppose the digital inputs were 10011000. The logical AND would be 10001000, as shown in the following illustration.

Logical AND Truth Table

Input Bit	Mask Bit	AND Result	Example
0	0	0	1 0 1 0 1 1 0 1 - AN mask = 173
0	1	0	1 0 0 1 1 0 0 0 - Input Bits
1	0	0	- - - - - - - -
1	1	1	1 0 0 0 1 0 0 0 - Logical AND

As with the XR command, leading zeros are inserted. In other words, AN5 is the same as AN005. If no number is received, the mask is set to all 0's.

Let's look at an example of how this works. Imagine we have a situation where the controller is to be interrupted only when bits 3, 5, and 6 are set and bits 4 and 7 are cleared. We don't care about bits 0, 1, and 2.

0	1	1	0	1	X	X	X

= Desired interrupt word

don't care

Remember the first of the two rules mentioned earlier; the XR mask consists of the bits which are to be set. In this example they would be bits 3, 5, and 6.

0	1	1	0	1	0	0	0

= XR104 (XR Mask - bits to be set)

Rule 2 states that the AN command specifies only the bits we want to look at. In this example those are bits 3, 4, 5, 6, and 7.

1	1	1	1	1	0	0	0

= AN248 (AN Mask - bits we are concerned with)

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Referring to the bit value chart, we can see that the XR mask should be set to value 104. In other words, execute the command XR104. The AND mask will be set to value 248; i.e. AN248. The following three tables show how the MN command works to produce the final result. In A, all conditions are met and the final result equals 0. Remember that when the final result equals 0, the computer will be interrupted. In B we have an example of bit 4 being set but all other conditions being met. Table C shows an example of bit 6 being cleared but all other conditions being met.

	A	B	C
Input	01101xxx	01111xxx	00101xxx
XR mask	01101000	01101000	01101000
Result 1	00000xxx	00010xxx	01000xxx
AN Mask	11111000	11111000	11111000
Final Result	00000000	00010000	01000000

In the examples "x" means that we don't care whether it is set or cleared. Notice that after the XOR operation the "don't care" bits are not changed. However, after the AND operation, those bits are always 0 regardless of their previous state.

DTx

The Digital Trigger command (DTx) provides a way to externally trigger the 3421A voltmeter. The DT command monitors the bit at address "x", and when it goes low, a voltmeter T3 trigger command is executed. Trigger command T3 is used to trigger the voltmeter to make a measurement from each channel in the channel list and store the readings. The channel list and measurement function must be set up prior to asserting the the DTx command. An example of using the DT command is provided in chapter 3.

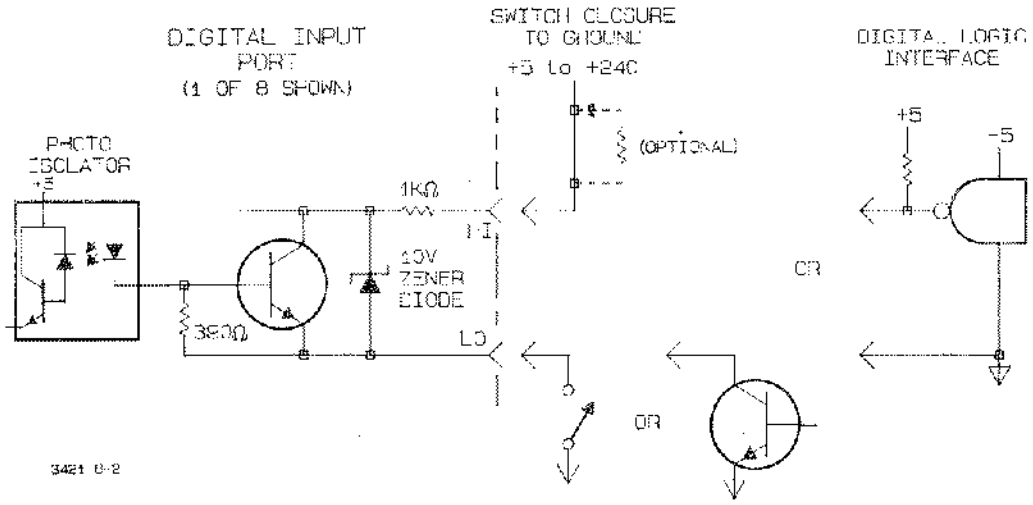
If any information is passed through the interface prior to the trigger, the digital trigger function will be aborted.

Working With the Input Port

Essentially, only two things are required when working with each bit of the input port; an external power supply and a switch. The switch may be a mechanical switch, a discrete transistor or integrated circuit, etc.

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The following illustration shows one bit of the input port in a typical configuration. Two connections are needed for each bit input. When the switch is closed, or the transistor turns on, the input bit light isolator turns on. This is the condition described previously as being ''set''. With the switch open the bit is ''cleared''. If one power supply is to be used with all 8-bits of the input port, it should be capable of providing a minimum of 200 mA per option card.



Output Port Overview

The output port contains 8 VMOS Field Effect Transistor (FET) switches. These switches are completely independent of each other and allow you to control such things as alarms and relays. A high switching voltage (<42VDC) and current (<300 mA) means that the output port can be employed in many different ways.

Standard Commands

The three STANDARD commands most commonly used with the output port are CLSx, OPNx, and WRTi,[abc]. The first two, CLSx and OPNx, allow control of individual switches in the port. WRTi, on the other hand, permits one command to control all 8 switches. In the discussion to follow, the word ''closed'' means that the switch is closed (low impedance) and ''clear'' means the switch is open (high impedance).

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CLSx, OPNx

The command CLSx (CLose Single switch x) "closes" the switch specified by x. OPNx performs just the opposite task, it clears the switch specified by x. The table below shows the switch address chart for the three different slots.

	Switch Address if card in slot#		
Switch#	Slot 0	Slot 1	Slot 2
0	0	10	20
1	1	11	21
2	2	12	22
3	3	13	23
4	4	14	24
5	5	15	25
6	6	16	26
7	7	17	27

If, for example, you have a digital I/O card in slot 1 and you wanted to close switch 5, execute CLS5. If you want to open switch 3, execute OPN3.

WRTi,[ab]c

To control all switches with one command use the WRTi,[ab]c command. The i represents the slot number for the digital I/O card. The value [ab]c is a decimal number(1 to 3 digits) equal to the sum of the values of the switches that you want closed. See the switch value chart below. If you want to close only switches 3, 4, and 5 and open all other switches in slot 1, regardless of their previous condition, execute the command WRT1,56. This example is shown below.

Switch Number	7	6	5	4	3	2	1	0
Switch Value If Closed	128	64	32	16	8	4	2	1

Example: 0 + 0 + 32 + 16 + 8 + 0 + 0 + 0 = 56

To make it easier for you to convert binary to decimal, here's a simple program to do the conversion for you. Simply enter the bit numbers that you want to be set. The program will return the decimal equivalent number.

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```
10 ! BINARY TO DECIMAL CONVERSION
20 A=0
30 DISP "HOW MANY BITS DO YOU WANT TO SET"
40 INPUT B@ IF B>=9 THEN 30
50 FOR I=1 TO B
60 DISP "BIT NUMBER?" @ INPUT N
70 A=A+2^N
80 NEXT I
90 DISP "DECIMAL VALUE =";A
100 END
```

Advanced Commands

The advanced instruction set provides added capabilities when using the output port. The two instructions from this set are DSi,[abc], and DCi[abc].

DSi,[ab]c

The **D**igital **S**ET command, DSi,[ab]c, closes the output switches on card "i" to the configuration specified by the decimal number abc. All switches not specified by [abc] remain unchanged. The value [abc] represents the sum of the values of the switches you wish to close. Use the switch value chart shown previously to determine the value abc. For example, if you want switches 1 and 5 closed in slot 2 and all other switches to remain in their previous state, execute the command DS2,34.

The DS command differs from the WRT command in that DS (and DC) affects only the switches specified in the command. The WRT command affects all switches on the assembly. For example, suppose that on a 44465A assembly (slot 0), switches 2, 3, and 4 are closed. Executing the command: DS0,1 would close switch number 1. Switches 2, 3, and 4 would remain closed. However, if the WRT0,2 command had been executed, switch 1 would be closed but switches 2, 3, and 4 would be opened. (Remember that WRT uses the sum of the decimal values rather than the bit numbers.)

DCi,[ab]c

The **D**igital **C**lear command, DCi,[ab]c, clears (opens) the switches specified in the same manner as the Digital Set command closes switches.

Working With the Output Port

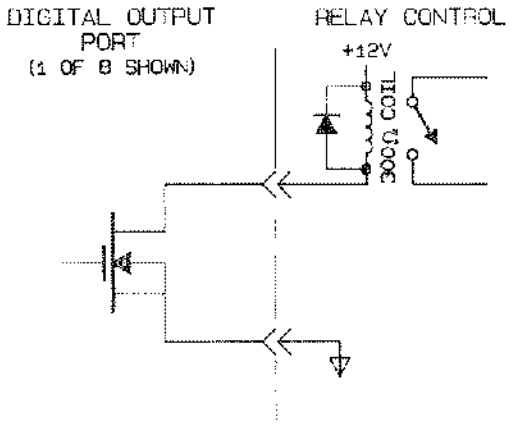
Although there are several ways to use the output port, the most common application is a switch closure to ground. In whatever way you use it, two things are required, a power supply and a load. The FET switches are designed for a maximum

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power supply voltage of 42 volts, The load must be designed to limit current through the switch to a maximum of 300mA. Consider the following two examples.

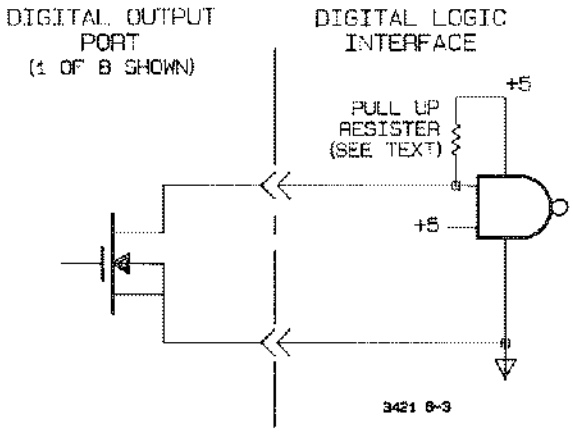
Relay Control

In this first example, one bit of the digital output port is used to control a relay. In this circuit, the relay was chosen because it has a 12 volt, 300 ohm coil. The 300 ohm coil limits the current to 40 mA. The diode across the relay coil must be there to prevent damage to the FET switch.



Digital Logic Interface

The second example demonstrates how the output port could be used to communicate with digital logic devices. The value of the pull-up resistors are determined by the type of logic family the output port will be driving. As a general rule, the following values will suffice: standard TTL, use 2.2KΩ; for LS TTL devices, use 10KΩ; for CMOS devices, use 50KΩ.



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Specifications

Input Port

Input Voltage Levels:

Low Voltage Maximum:	.8 V
High Voltage Minimum:	2.4 V
High Voltage Maximum:	24.0 V

Maximum Input Current for Low State: 100μA

Minimum Input Current for High State: 800μA

Maximum input current for High State (24V): 25mA

Monitor Functions:

Minimum pulse width:	100μS
Time from trigger to SRQ:	300μS

Output Port

Logic 1 (Closed): Low impedance, <2 Ohms, ≤300mA current, <.6V Drop across switch

Logic 0 (Open): High impedance, >10Mohms, ≤ +42V across switch.

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Chapter 7
Operator Maintenance

Introduction

Your 3421A Data Acquisition and Control Unit was engineered for ease of use, accuracy, and reliability. The instrument was carefully inspected before shipping and should be free of mechanical and electrical flaws and should be in proper working condition.

The information in this chapter covers the initial setup and installation of the 3421A and should be read before the instrument is installed for use. This chapter also includes warranty information, instructions on obtaining repair service, cleaning, etc.

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Accessories

The following table lists the available accessories and options for your 3421A. These accessories are offered to help you maximize the useability and convenience of your 3421A.

Description of Option/Accessory	Use this number when ordering with 3421A	Use this number when ordering separately
HP-IB Interface	Option 201	44461A
10-Channel Multiplexer with thermocouple compensation and connector block	Option 020* 021* 022*	44462A
Extra connector block for 10 channel Multiplexer	44463A	44463A
8-Bit Digital I/O Assembly with connector block	Option 050	44465A
Breadboard Assembly with connector block	Option 040	44464A
Extra connector block for Digital I/O or Breadboard	44466A	44466A
Six pairs of resistors for 10:1 divider, used on 10 channel multiplexer. One pair comes premounted (channel 2) on each assembly.	44469A	44469A
12 Volt Battery Option	Option 212	— — — —
Side handle Kit	Option 401	— — — —
Front Handle Kit	Option 907	— — — —
Rack Mount Kit	Option 908	— — — —
Rack Mount Kit with Front Handle	Option 909	— — — —
Carrying Case with Pocket for HP-41C/CV	11341A	11341A
Additional set of 3421A Documentation	Option 910	Order by part number
HP 41CV calculator, 82160A HP-IL interface, 82182A Time module, and 44468A DA/C Pac	Option 541	Order components separately
HP-82161A HP-IL Digital Cassette Drive	Option 561	82161A
HP-82162A HP-IL Printer	Option 562	82162A
Temperature Probe	10023A	10023A
500MHz RF Probe	11096A	11096A
Test lead kit	34118A	34118A
1 Metre HP-IB Cable 2 Metre HP-IB Cable 4 Metre HP-IB Cable 0.5 Metre HP-IB Cable	10833A 10833B 10833C 10833D	10833A 10833B 10833C 10833D
0.5 Metre HP-IL Cable 1 Metre HP-IL Cable 5 Metre HP-IL Cable	82167A 82167B 82167D	82167A 82167B 82167D

* Option 022 - has all 10 channels configured for multiplexing.
Option 021 - has channel 0 configured as an actuator; channels 1-9 configured for multiplexing.
Option 020 - has channels 0 and 1 configured as actuators; channels 2-9 configured for multiplexing.

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Preparation For Use

Unpacking Instructions

When you are unpacking the 3421A for the first time, make certain the options that you ordered have been installed in your 3421A. The following list of items should also be included with the 3421A:

Qty.	Item
1	3421A Operating, Programming, and Configuration Manual.
1	3421A Service Manual.

Also, make certain that the instrument and option assemblies that you ordered coincide with what you received. This includes line voltage options as well as HP-IB and other option assemblies.

Initial Inspection

Your 3421A was carefully inspected before it left the factory. It should be free of mars or scratches and in proper working order upon receipt. You should, however, inspect the instrument for any damage that may have occurred in transit. If the shipping container or cushioning material is damaged, it should be kept until the contents of the shipment have been checked for completeness and the instrument has been mechanically and electrically inspected. Procedures for checking the electrical performance of the 3421A are given in the 3421A SERVICE MANUAL (-hp-part number 03421-90008). If there is any mechanical damage, the contents are incomplete, or the instrument fails to pass its performance tests, promptly notify the nearest Hewlett-Packard office. A list of -hp- Sales and Service Offices is located in the back of this manual. If the shipping container is damaged, or the cushioning material shows signs of stress, notify the carrier as well as the Hewlett-Packard office. Save the shipping materials for the carrier.

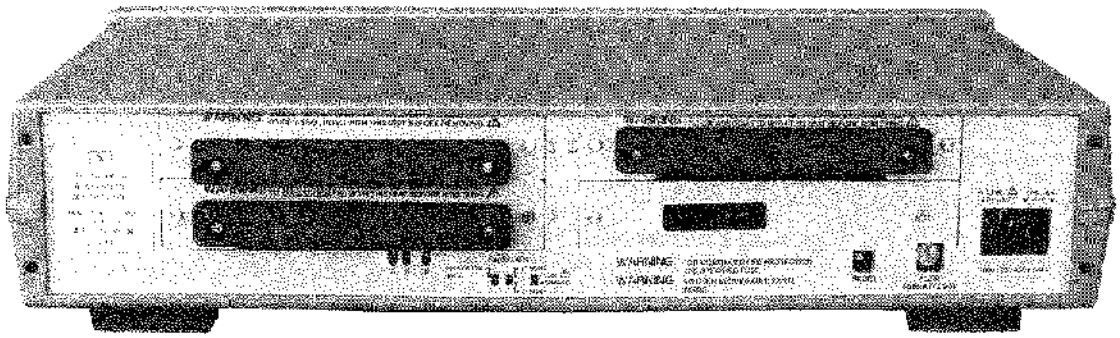
CAUTION

Before connecting the 3421A to an ac power source, verify that the ac power source matches the power requirements of the instrument as marked on the option label on the rear panel of the instrument. Only qualified service trained personnel should reconfigure the 3421A for a different power line voltage option.

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Power Requirements

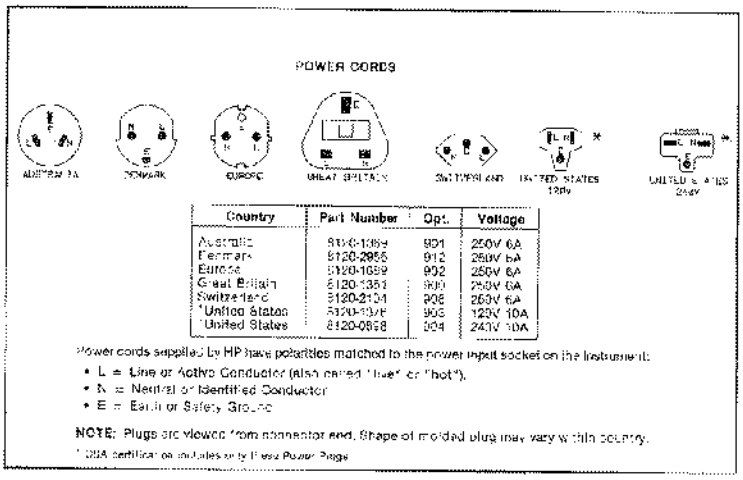
The 3421A requires a power source of 100, 120, 220, or 240 VAC (-10%, +5%), 48 to 440 Hz single phase. Maximum power consumption is 6 VA. Refer to the 3421A rear panel for the line voltage option label. Make certain the option marked on the label is the same as the nominal line voltage for your area. Also check the 50/60 Hz switch for the proper setting, i.e., up for a 60 Hz line and down for a 50 Hz line.



3421 Back Panel

Power Cords and Receptacles

The following illustration shows the various power cord configurations that are available to provide power to the 3421A. The -hp- part number shown directly below the individual power plug drawing is the part number for the power cord complete with plug. If the appropriate power cord is not included with the instrument, notify the nearest -hp- Sales and Service Office.



Power Cords

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Grounding Requirements

The instrument is equipped with a three-conductor ac power cable. The power cable must either be plugged into an approved three-contact electrical outlet or used with a three-contact to two-contact adapter with the grounding wire (green) firmly connected to an electrical ground (safety ground). The power jack and supplied power cable meet IEC (International Electrotechnical Commission) safety standards.

Power Line Fuse Replacement

The power line fuse is located on the rear panel of the 3421A in the lower right corner. To replace the fuse, turn the instruments power switch off and remove the power cord from the rear of the instrument. With a small flatblade screwdriver rotate the fuse terminal counterclockwise. Replace the fuse with the same type fuse. Reinstall the terminal and apply power. The following table lists the available power line options and the appropriate fuse.

Line Voltage Options

Option No.	Line Voltage	Frequency	Power Line Fuse
315	100VAC	50Hz	.15A Time Delay (HP Part Number 2110-0234)
316	100	60	
325	120	50	
326	120	60	
335	220	50	
336	220	60	
345	240	50	
346	240	60	

Installation Considerations

There are two items to keep in mind whether you are installing the 3421A in a rack or simply setting it on a test bench. First, do not set the 3421A where air blowing into the instrument may cause thermal gradients and cause errors in temperature measurements. Second, the REFerence junction on the 10-channel multiplexer assembly was calibrated with the 3421A in a horizontal position. Consequently the 3421A should be used in a horizontal position or temperature gradients may again cause errors in measurements. If the instrument is to be used in another position, the REFerence junction should be calibrated with the instrument in that position.

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WARNING

The 3421A uses latching relays on the 10 channel multiplexing assembly (option 020) and on the mainframe. The state of these relays can only be altered under program control. This is an advantage in the sense that, under most conditions of failure, the relays will remain in whatever state your program has set them. However, in case of power or equipment failure, any application requiring a failsafe method of insuring that the circuits under control are in a known state must be provided by the installer.

Safety Considerations

General safety precautions must be adhered to during all phases of operation of the 3421A. Failure to comply with these precautions or with specific warnings elsewhere in this manual, violates safety standards of design, manufacture, and intended use of this instrument. The Hewlett-Packard Company assumes no liability for the customer's failure to comply with these requirements.

Operating personnel must not remove instrument covers. Component replacement must be made by qualified service trained personnel with a knowledge of the hazards involved. Do not operate the instrument in the presence of flammable gases or fumes. Operation of any electrical instrument in such an environment consitutes a definite safety hazard.

Warnings and cautions precede potentially dangerous procedures throughout this manual. Instructions contained in the warnings and cautions must be followed. Safety symbols used on the instrument or in the manual include the following:

WARNING	The WARNING sign denotes a hazard. It calls attention to a procedure, practice, condition, or the like, which, if not correctly performed or adhered to, could result in injury or death to personnel.
CAUTION	The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, condition, or the like, which, if not correctly performed or adhered to, could result in damage or destruction to all or part of the product.
NOTE	The NOTE sign denotes important information. It calls attention to a procedure, practice, condition, or the like which is essential to highlight.

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INSTRUCTION MANUAL SYMBOL. The product will be marked with this symbol when it is necessary for the user to refer to the instruction manual in order to protect against damage to the instrument.

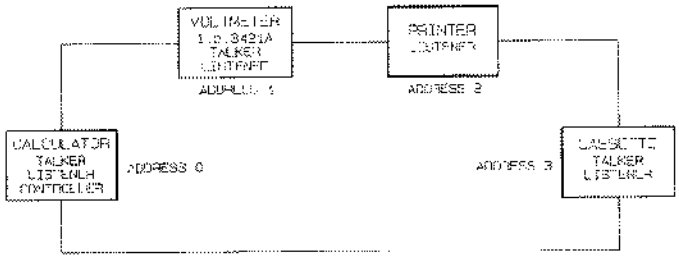
Indicates dangerous voltage (terminal fed from the interior by voltages exceeding 1000 volts must be so marked).

Alternating Voltage/Current

Direct Voltage/Current

Interface Connections

The -hp- Model 3421A is compatible with the Hewlett-Packard Interface Loop (HP-IL). HP-IL is an easy to use interface that allows interaction and control between several -hp- controllers, such as the 41C/CV calculator or 85A desktop, and instruments like the 3421A or -hp- 3468A. Instruments are connected together in series, forming a "loop". Refer to the figure below. The 3421A also has an option 201 which provides switch selectable HP-IB or HP-IL. HP-IB (Hewlett-Packard Interface Bus) is Hewlett-Packard's implementation of IEEE Std. 488-1978, "Standard Digital Interface for Programmable Instrumentation."



HP-IL

Although the 3421A may be connected anywhere in the loop, delays in triggering will be reduced if the 3421A is the first device in the loop. HP-IL connections to the 3421A are made by two cables, one going to the previous instrument in the loop (RECEIVE) and the other going to the next instrument in the loop (TRANSMIT). All of the interface cables must form a continuous loop. All connectors are designed for proper orientation. To connect a device, such as the 3421A, in the loop, first turn off the calculator and the device to be added to the loop. Then, disconnect the loop in one place and connect the 3421A into the loop at that place. All devices must be turned on for the interface to work properly. The calculator/controller should be the last device turned on as it re-assigns new addresses to each device when turned on. Total cable length between any two consecutive devices in the loop must not exceed 10 metres (33 feet) for standard HP-IL cable.

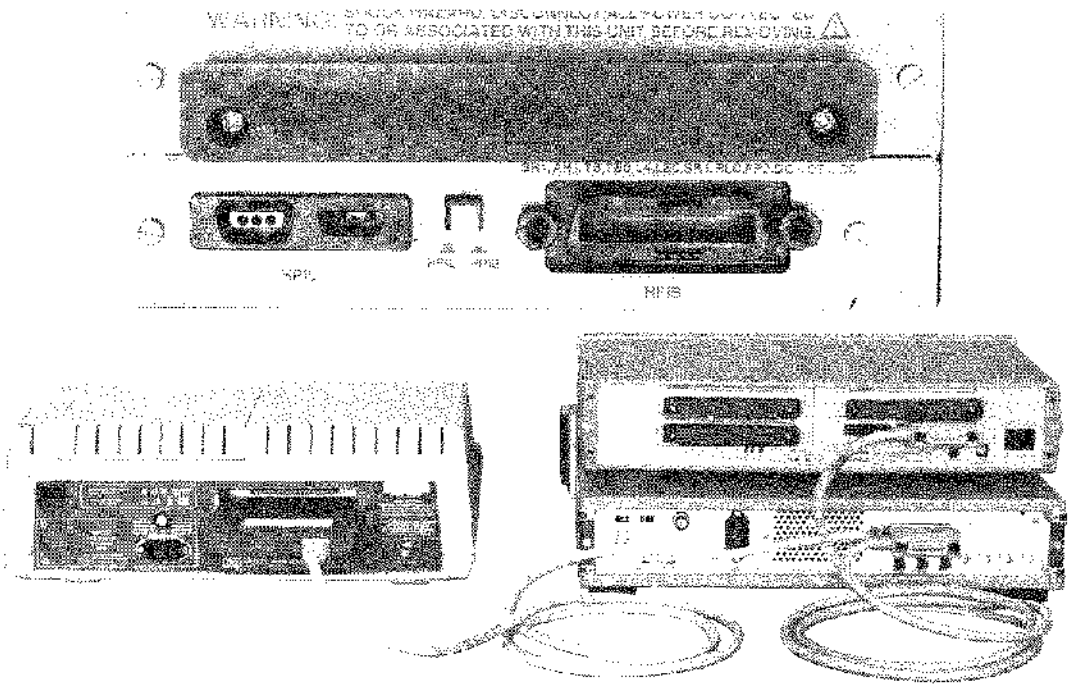
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HP-IL Address Selection

Each device in the loop is assigned a unique address - a number from 1 to 30 - allowing the controller to specify and control individual devices. The 3421A has a default turn-on address of 09, however, the controller will sequentially re-address each device in the loop. The addresses start with address 1 for the first device in the loop after the calculator in the direction of information transfer. In this way, each instrument has a unique address, which it stores internally.

HP-IB

The 3421A with option 201 provides switch selectable HP-IL or HP-IB* interfaces. The photograph below shows the rear panel of the 3421A with the option and points out the switch. Connection to HP-IB is made by an interface cable to the 24 pin HP-IB connector located on the rear panel. A typical interconnection is shown below in which system inteconnection is made by two interface cables. The ends of the cables have both a male and female connector to enable connections to other cables. As many as 15 instruments (including the controller) can be connected by the same interface bus. However, the maximum length of cable that can effectively be used to connect a group of instruments should not exceed 2 metres (6.5 feet) times the number of instruments to be connected, or 20 metres (65.6 feet), whichever is less.



HP-IB and Two Cable System

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HP-IB Address Selection

The HP-IB address for the 3421A is determined by the setting of five switches located inside the instrument case. The 3421A leaves the factory with the address switches set to decimal code "09". Changing the HP-IB address requires a qualified service trained technician. Refer to the 3421A Option 201 Service Manual.

Warranty Information

Certification

Hewlett-Packard Company certifies that this product met its published specifications at the time of shipment from the factory. Hewlett-Packard further certifies that its calibration measurements are traceable to the United States National Bureau of Standards, to the extent allowed by the bureau's calibration facility, and to the calibration facilities of other International Standards Organization members.

Warranty

This Hewlett-Packard product is warranted against defects in material and workmanship for a period of one year from the date of shipment. During the warranty period, Hewlett-Packard Company will, at its option, either repair or replace products which prove to be defective.

For warranty service or repair, this product must be returned to a service facility designated by -hp-. Buyer shall prepay shipping charges to -hp- and -hp- shall pay shipping charges to return the product to Buyer. However, Buyer shall pay all shipping charges, duties, and taxes for products returned to -hp- from another country.

Hewlett-Packard warrants that its software and firmware designated by -hp- for use with an instrument will execute its programming instructions when properly installed on that instrument. Hewlett-Packard does not warrant that the operation of the instrument, or software, or firmware will be uninterrupted or error free.

Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer, Buyer-supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

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NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HEWLETT-PACKARD SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Exclusive Remedies

THE REMEDIES PROVIDED HEREIN ARE BUYERS SOLE AND EXCLUSIVE REMEDIES. HEWLETT-PACKARD SHALL NOT BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER BASED ON CONTRACT, TORT, OR ANY OTHER LEGAL THEORY.

Assistance

Product maintenance agreements and other customer assistance agreements are available for Hewlett-Packard products.

For any assistance, contact your nearest Hewlett-Packard Sales and Service Office. Addresses are provided in the back of this manual.

In addition to the above warranty, the following LIMITATION OF WARRANTY applies to the option 040, Breadboard Assembly:

Limitation of Warranty for Option 040

The foregoing warranty shall not apply to defects resulting from improper or inadequate maintenance by Buyer. Buyer supplied software or interfacing, unauthorized modification or misuse, operation outside of the environmental specifications for the product, or improper site preparation or maintenance.

The design and implementation of any circuit used on this product is solely the responsibility of the Buyer. Hewlett-Packard Company does not warrant the Buyers circuitry or malfunctions of the 3421A or plug-in options that result from the Buyers circuitry. In addition, -hp- does not warrant any damage that occurs as a result of the Buyers circuit, including but not limited to the following:

1. Analog and digital sections are interconnected.
2. 3421A power supply limitations are exceeded.
3. Component height/protrusion restrictions are violated.
4. Internal 3421A DVM voltage specifications are violated.
5. Maximum input voltage on the digital lines is exceeded.
6. The trace specifications listed in Chapter 9 of this manual are exceeded.

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NO OTHER WARRANTY IS EXPRESSED OR IMPLIED. HEWLETT-PACKARD SPECIFICALLY DISCLAIMS THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE.

Specifications

The specifications for the 3421A are the performance characteristics of the instrument which are certified. These specifications are listed at the end of this chapter, and are the performance standards or limits against which the instrument is tested. Included in the table are some supplemental characteristics of the 3421A. These should be considered as additional and general information for you, the user. Because of the many operational capabilities of the 3421A, exercise care when checking the instruments specifications.

Any changes in specifications due to manufacturing changes, design, or traceability to the National Bureau of Standards will be covered in a manual change supplement.

NOTE

Specification for 40°C >65% relative humidity are verified by a 5 day type test.

Environmental Requirements

When the 3421A is calibrated, careful note should be taken of the ambient temperature. In order to meet and maintain the specifications listed in this chapter, the 3421A should be operated within ± 5°C (±9°F) of the ambient calibration temperature. This temperature is also called the reference temperature. As it is shipped from the factory, the 3421A should be operated within an ambient temperature range of 23°C ± 5°C (73°F ± 9°F). The instrument may be operated within an ambient temperature range of 0°C to 55°C (+32°F to 131°F) but with reduced accuracy.

WARNING

To prevent potential electrical or fire hazard, do not expose the 3421A to rain or moisture.

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How to Obtain Repair Service

You may have your 3421A repaired at your local -hp- service center at anytime, whether it is under warranty or not. There is a charge for repairs after the one year warranty period. Contact your local Sales and Service Office for shipping instructions prior to returning the instrument. A list of Sales and Service Offices is located in the back of this manual.

Serial Number

Each 3421A carries its own serial number on a plate on the rear panel. Each of the 3421A option assemblies will also have a Date Code stamped on it. It is recommended that owners keep a separate record of these numbers. Should your unit be lost or stolen, the complete serial number is often necessary for tracing and recovery, as well as insurance claims.

General Shipping Instructions

Should you ever need to ship your 3421A, be sure it is packaged in a protective package (use the original shipping container and cushioning material) to avoid transit damage. Such damage is not covered by the warranty. Hewlett-Packard suggests that you always insure shipments. Attach a tag to the instrument identifying the owner and indicating the service or repair needed. Include the model number and full serial number of the instrument and/or option cards. In any correspondence, identify the instrument by model number and full serial number.

Further Considerations

Cleaning

Disconnect the 3421A from its ac power source before cleaning. Also, remove all sources of power from the option assemblies. The instrument can be cleaned with a soft cloth dampened either in clean water or in water containing a mild detergent. Do not use an excessively wet cloth, or allow water inside the instrument. Do not use any abrasive cleaners, especially on the display. Do not press hard on the display.

The panel area surrounding the input terminals should not be touched because oils on the instrument surface caused by fingerprints may cause leakage paths and decrease the input impedance. To maintain the high input impedance of the 3421A, the input terminal area should be cleaned periodically with a cotton swab dipped in isopropyl alcohol and then rinsed with deionized water. Let the panel thoroughly dry before using.

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Detailed Specifications

DC VOLTAGE

Input Characteristics

Range	Maximum Display (5½ Digit)	Resolution 5½ Digit	Resolution 4½ Digit	Resolution 3½ Digit	Input Resistance	0-40°C @ 65% <RH ≤95% Input Resistance	Maximum Input Voltage
0.3V	.3010000	1 μV	10 μV	100 μV	10^{10}	10^{8}	±350 Vpeak Hi-earth, Hi Lo, or between any two terminals. ±150 Vpeak Lo-earth.
3 V	3.01000	10 μV	100 μ	1 mV	10^{10}	10^{8}	
30 V	30.0100	100 μV	1 mV	10 mV	10M ± 1%	10M + 1% − 3%	
300 V	301.000	1 mV	10 mV	100 mV	10M + 1%	10M + 1% − 3%	

Measurement Accuracy: ±(% of reading + number of counts). Auto-zero on.
(20°C ≤ calibration temperature ≤ 30°C)

24 hours: 23°C ± 1°C operating temperature after 1 hour warmup. For less than 1 hour warmup use 90 day specs.

Range	5½ Digit	4½ Digit	3½ Digit
0.3 V	.0050 − 5	.0050 + 1	.0050 − 1
3 V	.0035 − 3	.0035 + 1	.0035 − 1
30 V	.0050 − 3	.0050 + 1	.0050 − 1
300 V	.0055 − 3	.0055 + 1	.0.0055 − 1

90 days: 23°C ± 5°C operating temperature

Range	5½ Digit	4½ Digit	3½ Digit
0.3 V	.0088 − 6	.0088 + 1	.0088 + 1
3 V	.0072 − 3	.0072 + 1	.0072 + 1
30 V	.0087 − 3	.0087 + 1	.0087 + 1
300 V	.0089 − 3	.0089 + 1	.0089 + 1

1 year: 23°C ± 5°C operating temperature

Range	5½ Digit	4½ Digit	3½ Digit
0.3 V	.0194 + 6	.0194 + 1	.0194 + 1
3 V	.0181 + 3	.0181 + 1	.0181 + 1
30 V	.0195 + 3	.0195 + 1	.0195 + 1
300 V	.0195 + 3	.0195 + 1	.0195 + 1

Temperature Coefficient: Add to Measurement Accuracy ±(% of reading + number of counts)/°C for each °C outside of calibration temperature ± 5°C

Range	5½ Digit	4½ Digit	3½ Digit
0.3V	0.0008 + 0.5	0.0008 + 0.05	0.0008 + 0
3 V	0.0007 + 0.05	0.0007 + 0	0.0007 + 0
30 V	0.0008 + 0.5	0.0008 + 0.05	0.0008 + 0
300 V	0.0007 + 0.05	0.0007 + 0	0.0007 + 0

Auto-zero Off: Add to Measurement Accuracy ± (number of counts). For 24 hours in a stable environment (temperature within ± 1°C of the temperature when auto-zero is turned off).

Range	5½ Digit	4½ Digit	3½ Digit
0.3V	11	1	0
3 V	3	0	0
30 V	11	1	0
300 V	3	0	0

Noise Rejection: For 50, 60 Hz ± 0.1% (depending on option) 1 kΩ unbalance in Lo. Auto-zero on.

In dB	5½ Digit	4½ Digit	3½ Digit	0-40°C @ 65% <RH ≤95% 5½ Digit	4½ Digit	3½ Digit
AC NMR	80	59	0	80	59	0
AC ECMR	140	120	60	140	120	80
DC CMR	140	140	140	120	120	120

RESISTANCE (2-wire Ω, 4-wire Ω)

Input Characteristics

Range	Maximum Reading 5½ Digit	Resolution 5½ Digit	Resolution 4½ Digit	Resolution 3½ Digit	Current Through Unknown	Max. Open Circuit Voltage
300 Ω	301.000	1 mΩ	10 mΩ	100 mΩ	1 mA	6.5
3 k	3.01000	10 mΩ	100 mΩ	1 Ω	1 mA	6.5
30 k	30.1000	100 mΩ	1 Ω	10 Ω	100 μA	6.5
300 k	301.000	1 Ω	10 Ω	100 Ω	10 μA	5.5
3 M	3.01000	10 Ω	100 Ω	1 kΩ	1 μA	4.5
30 M	30.1000	100 Ω	1 kΩ	10 kΩ	100 nA	4.5

Non-destructive over load ± 300 Volts peak.
Short-term overload ± 650 Volts peak.

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Detailed Specifications (Cont'd)

RESISTANCE (2-wire Ω, 4-wire Ω) (Continued)

Measurement Accuracy: ±(% of reading + number of counts).
Auto-zero on, 4-wire ohms.

5½ Digit Mode

Operating Temperature	23°C ± 1°C	23°C ± 5°C	23°C ± 5°C
Range	24 Hour	90 Day	1 Year
300 Ω	.0045 + 5	.012 + 6	.017 + 6
3 k	.0035 + 3	.011 + 3	.016 + 3
30 k	.0035 + 3	.011 + 3	.016 + 3
300 k	.0035 + 3	.011 + 3	.016 + 3
3 M	.010 + 3	.014 + 3	.018 + 3
30 M	.092 + 3	.107 + 3	.115 + 3

Operating Environment	0-40°C @ 65% <RH≤95%		
Range	24 Hour	90 Day	1 Year
300 Ω	.0046 + 4	.012 + 6	.017 + 6
3 k	.0047 + 3	.011 + 3	.017 + 3
30 k	.0318 + 3	.0335 + 3	.0354 + 3
300 k	.315 + 3	.315 + 3	.315 + 3
3 M	3.08 + 3	3.08 + 3	3.08 + 3
30 M	25.2% + 3	25.2% + 3	25.2% + 3

4½ Digit Mode

Operating Temperature	23°C ± 1°C	23°C ± 5°C	23°C ± 5°C
Range	24 Hour	90 Day	1 Year
300 Ω	.0045 + 1	.012 + 1	.017 + 1
3 k	.0035 + 1	.011 + 1	.016 + 1
30 k	.0035 + 1	.011 + 1	.016 + 1
300 k	.0035 + 1	.011 + 1	.016 + 1
3 M	.010 + 1	.014 + 1	.018 + 1
30 M	.097 + 1	.114 + 1	.123 + 1

Operating Environment	0-40°C @ 65% <RH<95%		
Range	24 Hour	90 Day	1 Year
300 Ω	.0046 + 1	.012 + 1	.017 + 1
3 k	.0047 + 1	.011 + 1	.017 + 1
30 k	.0318 + 1	.0335 + 1	.0354 + 1
300 k	.315 + 1	.315 + 1	.315 + 1
3 M	3.08 + 1	3.08 + 1	3.08 + 1
30 M	25.2% + 1	25.2% + 1	25.2% + 1

3½ Digit Mode

Operating Temperature	23°C ± 1°C	23°C ± 5°C	23°C ± 5°C
Range	24 Hour	90 Day	1 Year
300 Ω	.0045 + 1	.012 + 1	.017 + 1
3 k	.0035 + 1	.011 + 1	.016 + 1
30 k	.0035 + 1	.011 + 1	.016 + 1
300 k	.0035 + 1	.011 + 1	.016 + 1
3 M*	.076 + 1	.082 + 1	.087 + 1
30 M*	.74 + 1	.78 + 1	.79 + 1

*3½ digit 3M and 30M spec is for ac operation with floating input. Measurement noise will decrease with LO connected to EARTH or in battery operation in which case the spec is the same as for 5½ digit with 0 counts offset.

Operating Environment	0-40°C @ 65% <RH<95%		
Range	24 Hour	90 Day	1 Year
300 Ω	.0046 + 1	.012 + 1	.017 + 1
3 k	.0047 + 1	.011 + 1	.017 + 1
30 k	.0318 + 1	.0318 + 1	.0318 + 1
300 k	.315 + 1	.315 + 1	.315 + 1
3 M*	3.08 + 1	3.08 + 1	3.08 + 1
30 M*	25.2% + 1	25.2% + 1	25.2% + 1

*3½ digit 3M and 30M spec is for ac operation with floating input. Measurement noise will decrease with LO connected to EARTH or in battery operation in which case the spec is the same as for 5½ digit with 0 counts offset.

First reading is in specification with default delay and 200 pF of capacitance.

2-wire ohms accuracy is the same as 4-wire ohms except add a maximum of 4Ω offset.

Temperature Coefficient of Measurement Accuracy:

0°C to 18°C, 28°C to 55°C
5½ digit display, auto-zero on
±(% reading + number of counts)/°C

Range	Temperature Coefficient
300 Ω	.0009 + 5
3 k	.0009 + .05
30 k	.0009 + .05
300 k	.0009 + .05
3 M	.0021 + .05
30 M	.021 + .05

For 4 digits, multiply counts by .1
For 3 digits, multiply counts by .01

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Detailed Specifications (Cont'd)

RESISTANCE (2-wire Ω, 4-wire Ω) (Continued)

Auto-zero Off: (5½ digits)

For a stable environment (±1°C) add 11 counts for 300Ω range, 3 counts for 3k through 300k ranges, 8 counts for 3M and 33 counts for 30M range. For 4½ or 3½ digits, multiply counts by .1 and .01 respectively. Changes in lead resistance are not corrected in 4-wire ohms with auto-zero off.

Current Source Accuracy: 2.7%

Maximum Lead Impedance: 4-wire Ω

Ω sense leads	10k	All ranges
Ω source lo lead	1/30 of full scale	All ranges
Ω source hi lead	1/3 of full scale 3kΩ for 300Ω	3k through 30M

Source Lead	300Ω	3kΩ	30kΩ	300kΩ	3MΩ	30MΩ
Lo Hi	10 3k	100 1k	1k 10k	10k 100k	100k 1M	1M 10M

AC VOLTAGE

Input Characteristics

Range	Maximum Display (4½ Digit)	4½ Digit Resolution	Input Resistance	Maximum Input Voltage
3 V	3.0100	100μV	10MΩ ± 1%	Hi – Lo +3V peak Lo terminal to earth ±150V peak
30 V	30.100	1 mV		

Measurement Accuracy*: ±(% Reading + Counts)
(90 days)

	20 Hz–1kHz	45 Hz–500 Hz	Temperature Coefficient ±(%Reading + Counts)/°C 0–18°C, 28–55°C
3½ Digits	1 + 6	0.5 + 6	.01 + 7
4½ Digits	1 + 60	0.5 + 60	.01 + 7

*These specifications assume: V_{in} > 0.3V (3V Range)
V_{in} > 3V (30V Range)

3421A READING SPEEDS – INTO INTERNAL MEMORY (READINGS/SEC) REPEAT ON ONE CHANNEL

	Z1F1	Z0F1	Z1F2	Z0F2	Z1F3	Z0F3	F6		F7
N5	2.26	4.08			2.26	4.12	1.05	G1	8.4
N4	15.85	23.02	.97	1.11	15.85	24.31	1.05	G0	98
N3	30.96	38.56	1.37	1.41	30.93	38.31	1.05	G1	1

RANDOM CHANNEL

	Z1F1	Z0F1	Z1F2	Z0F2	Z1F3	Z0F3	F6		F7
N5	2.19	3.88			2.19	3.89	.98	G1	7.69
N4	13.18	18.24	.90	1.08	13.20	18.61	.98	G0	.97
N3	22.22	25.99	1.35	1.39	22.19	26.01	.98	G1	.1

N5, N4, N3 = 5½, 4½, 3½ digit mode

Z1 = Auto-Zero On
Z0 = Auto-Zero Off
F1 = DC Volts
F2 = AC Volts
F3 = Ohms
F6 = Temperature (T-type)
F7 = Frequency
G-1 = .1 second gate time
G0 = 1 second gate time
G1 = 10 second gate time

COUNTER

AC coupled zero crossing

Frequency range:

1 Hz to 10 kHz with rise time < 1.5 ms
10 Hz to 10 kHz with rise time > 1.5 ms

Sensitivity: 600 mV p-p

Minimum pulse width (5V):

50 μsec, 5% duty cycle minimum

Accuracy: .05% of reading ± 1 LSB

Maximum input voltage: 300V

Maximum DC offset: 2V

Input impedance: 10M ± 1 – 10%

TOTALIZE MODE

Minimum pulse width (5V):

50 μsec, 5% duty cycle minimum for signals with period 1 second

Sensitivity: 600 mV

Maximum counts: 65,535

Maximum rise time for signals less than 10 Hz: 1.5 ms

Minimum pulse period: 100 μsec

Maximum input voltage: 300V

Maximum DC offset: 2V

Input impedance: 10M + 1 – 10%

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Detailed Specifications (Cont'd)

BATTERY LIFE

Battery life from full charge:

HP-IL – 12 hours minimum

HP-IB – 6 hours minimum

Battery charge rate from minimum to full charge:

16 hours if 3421A off or asleep

24 hours if 3421A is on

OPTION 020, 021, 022
10 CHANNEL MULTIPLEXING ASSEMBLY

Voltage (Scan)	±350 V peak Hi-earth, Hi-Lo, or between any two terminals ±150 V peak Lo-earth 250 Vac 150 VA Maximum
Voltage (Actuate)	30 Vdc 250 Vac 2A Maximum
Contact Resistance (Actuate)	<1.4Ω
Thermal Offset (Scan)	<3μV
Average Switch Life	5×10^6 operations with proper contact protection
Maximum Switching Rate	50/sec.
Open Contact Capacitance	<15 pF
Closed Channel Capacitance	<90 pF with 1 Option 020 <130 pF with 2 Option 020 <170 pF with 3 Option 020
Interchannel Capacitance	<30 pF

Isolation Resistance	0-40°C @ RH ≤ 65%	0-40°C @ 65% < RH ≤ 95%
HI to LO	10^{11}	10^9
HI to EARTH	10^{11}	10^9
LO to EARTH	10^{11}	10^9

Frequency Response
(50Ω source) 1 MHz
(1 Meg source) 1 kHz

All relay scans break before make.
Relay configuration at shipment:

Option	Channel	Mode
020	0,1 2-9	Actuate 1 of N. Scan. 150 VA Max.
021	0 1-9	Actuate 1 of N. Scan. 150 VA Max.
022	0-9	1 of N. Scan. 150 VA Max.

REFERENCE JUNCTION COMPENSATION

Operating Temperature 23 ± 5°C	Accuracy
Static Environment (1 hr. 1°C deviations)	± 1°C
Dynamic Environment (5°C step or 5°C/hour maximum rate of change)	± 3°C

Temperature coefficient for 0-18°C/28-50°C operating ranges

Add to measurement accuracy:
.05°C for each °C outside of 23 ± 5°C

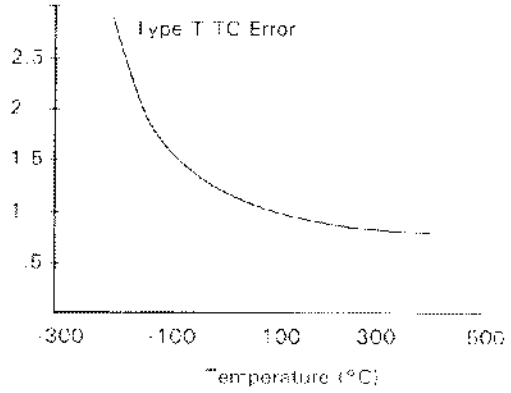
TYPE T THERMOCOUPLE COMPENSATION

Range: −200°C to + 400°C

Accuracy: Includes reference junction error, thermal offset, dvm error and curve fit. It does not include wire errors.

TYPE T THERMOCOUPLE
COMPENSATION
Range: −200°C to + 400°C

Accuracy: Includes reference junction error, thermal offset, dvm error and curve fit. It does not include wire errors.



Temperature Coefficient:

.05°C/°C (0 – 18° C, 28 – 55°C)

High Voltage Divider (Option 020 with 44469A):

Z_{in}: 1 MΩ ± 1%
C_{in}: ≤ 25 pF
Add 1% Reading error when using divider

Maximum Input Voltage:

250 V RMS Hi-Lo
±350 V peak – Hi terminal to earth
±150 V peak – Lo terminal to earth

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Detailed Specifications (Cont'd)

OPTION 050
DIGITAL I/O ASSEMBLY

All terminals ± 360V max. to earth
Isolated input specs: 8 bits wide 0 7
Input voltage levels:
Low voltage maximum .8V
High voltage minimum 2.0V
High voltage maximum (Hi-Lo) 24.0V
High voltage maximum (between any terminal and earth ground) ± 42V
Maximum input current at low state: 100 μA
Minimum input current at high state: 800 μA
Maximum input current at high state (24V in): 25 mA
Logic polarity: Positive true
Monitor mode (generates SRQ):
Minimum pulse width: 1ms in DO; 10ms in DI
Trigger latch: high or low level
Masking: any combination of the 8 bits
Time from trigger to SRQ: 1 to 10ms
Entire 8 bits latched when trigger received
Isolated output specs: 8 bits wide 8 – 15 DMOS FETS

Input	Output Characteristics
Logic 1	Low impedance 2Ω, sink 300 mA, 180 mW
Logic 0	High impedance 10MΩ, 0 to + 42V across switch (1 watt zener protection for inductive loads), or between any terminal and earth ground.

Each bit individually controlled

OPTION 040
BREADBOARD ASSEMBLY

Board Space: 95 sq. cm. (14.75 sq. in.)
Maximum Voltage: ±350 Vpeak Hi-earth, Hi-Lo or between any two terminals
±150 Vpeak Lo-earth
Power Available: 5 V, 35 mA; 6 V, 150 mA
Hole Sizes: .046
Grid: .100"
Connectors: 22 pin edge (solder)
Component Lead Length: 0.25"
Component Lead Height: 0.5"
Maximum Power Dissipation: 0.5 watts

OPTION 212
12 VOLT BATTERY OPTION

NOTE

To maintain these specifications the external 12V source must have good load regulation and the lead resistance specifications outlined in the Option 212 installation and Service Manual must be observed.

Input Voltage: 11Vdc to 15.3Vdc*

Input Hysteresis: 11V (drop out)*
12V (start up)*

Electronic Shutdown (Crowbar Threshold) Voltage: 16.01Vdc to 16.86Vdc

Common Mode Rejection:
Under normal operating conditions, the dc common mode rejection specification is the same as the mainframe specification without this option (140 dB). However, at 40°C, 65% relative humidity and above, the dc common mode rejection is degraded to 110 dB when the option is used with a grounded battery.

*The input voltage and input hysteresis specifications imply that the mainframe power supply will start up with a minimum external source voltage of 12 Vdc, and will continue to operate until the external source voltage drops to 11 Vdc (+ .2Vdc).

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Section II
Option Assembly Installation and Configuration

WARNING

Chapters 8 and 9 of this 3421A Operating, Programming, and Configuration Manual were written for service trained personnel only. Only qualified service trained personnel with an understanding of electronic circuitry and the hazards involved should remove, configure, and reinstall the 3421A option assemblies.

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Chapter 8
Installation and Configuration

Introduction

This chapter has been written specifically for the trained service technician. It provides the necessary information for a person with a knowledge of electronics to remove, configure and install the 3421A option assemblies. Currently available option assemblies are: the 44462A 10 Channel Multiplexer Assembly, the 44465A Digital I/O Assembly, and the 44464A Breadboard Assembly. Carefully read through this chapter and observe all cautions and warnings.

This chapter is divided into three sections; General Option Removal/Installation Procedures, Configuring the 44462A 10 Channel Multiplexing Assembly, and Wiring the 44465A 8 Bit Digital I/O Assembly. Each section contains simplified schematics, illustrations, and/or photographs to enhance the description of the procedures. The Breadboard assembly is covered in Chapter 9.

WARNING

Only qualified service trained personnel should remove, configure, and re-install the 3421A option assemblies.

LETHAL voltages may be present on the option assemblies even though the 3421A is disconnected from the AC power line. Before ANY handling or servicing of the option assemblies takes place, make certain that all external sources of electrical power to the option assemblies have been removed. Read the Safety Summary in Chapter 1 of this manual.

General Option Removal/Installation Procedures

This section of the chapter provides general guidelines to help take some of the guesswork out of removing, configuring and installing the option assemblies. In addition, this section shows you how to set the address switches on the HP-IB option board.

The option assemblies should be removed from the 3421A before they can be reconfigured. If you need only to connect the wires from your external transducers to the option assemblies, refer to the specific option later in this chapter.

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WARNING

Disconnect the 3421A power cord from the back of the 3421A prior to removing the top cover.

To prevent serious personnel injury, caution must be exercised when working with the option assemblies. Electrical shock hazards (up to 350 volts peak) may exist on the 44462A assembly from the device(s) under test. Make certain that all wires to the option assemblies are free of voltage sources prior to removing or installing the option assemblies.

CAUTION

Use clean handling techniques and anti-static procedures when removing, configuring, and installing the option assemblies. The 44462A Multiplexing Assembly is a high impedance circuit board and must be kept clean to ensure compliance with specifications. The option assemblies as well as the 3421A motherboard contains CMOS devices which are susceptible to static discharges.

Disassembly/Option Removal

If wiring connections to external devices or transducers have already been made to the option assembly terminal blocks, you should first remove the terminal blocks. This is accomplished by:

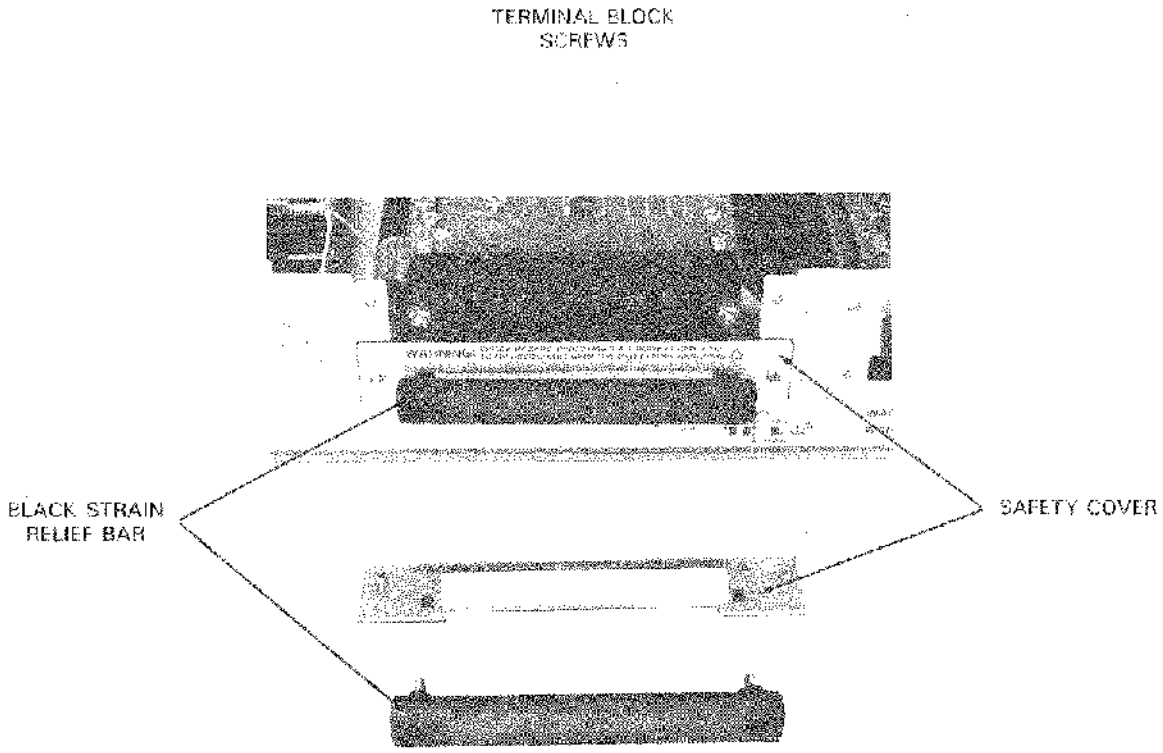
1. Make certain that all external sources of electrical power have been removed from the terminal blocks before starting the removal procedures. Also, make certain that the 3421A POWER switch is in the 'off' position and the ac power cord removed.

2. Removing the two screws holding the black strain relief bar.

3. Remove the grey "WARNING" safety cover. The two screws holding the cover are captive to the cover.

4. Loosen the two screws holding the terminal block to the option circuit board and then remove the terminal block.

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To remove the option assemblies the 3421A case will need to be disassembled. Perform the following procedures very carefully. When removing the option assemblies take careful note of which option was originally installed in each slot. As you are disassembling the 3421A, carefully observe the orientation of the various plugs and the cable routing as they must be properly returned when re-assembling the instrument. In the following discussion, the front panel of the 3421A should be facing you.

NOTE

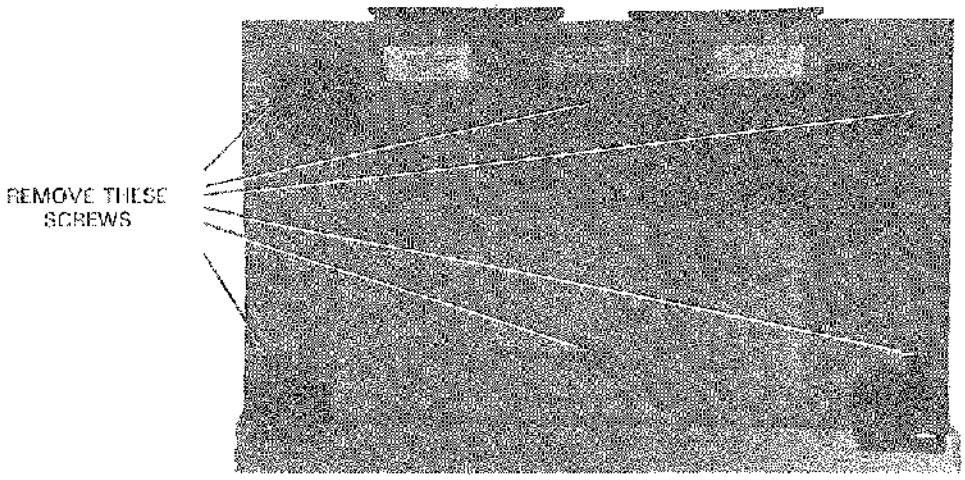
When re-installing the options, make certain that the option that was removed from slot 0 is returned to slot 0, likewise with slots 1 and 2. This is important for two reasons. First, if a computer program was written for a certain option in a known slot, reinstalling the option in a different slot may cause the program or test to fail. Second, measurement errors may result if a 44462A Multiplexer option is not re-installed in the same slot it was removed from. This is due to each board having an individual reference junction calibration.

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3421A Disassembly

To disassemble the instrument, do the following:

1. Turn the instrument upside down. This is preferably done on top of a protective mat to reduce scratching or marring the cabinet. Loosen the six screws on the bottom of the instrument.



2. Holding the top cover in place, turn the instrument upright. The six screws are captive to the bottom cover and will not fall out. Remove the top cover.

3. Locate the main battery fuse toward the right rear of the instrument and remove it from its socket. This will reduce the possibility of an accidentally dropped screw or standoff from causing any problem.

4. If the black strain relief bars and grey 'WARNING' safety covers have not been removed from the rear panel, they should be removed at this time.

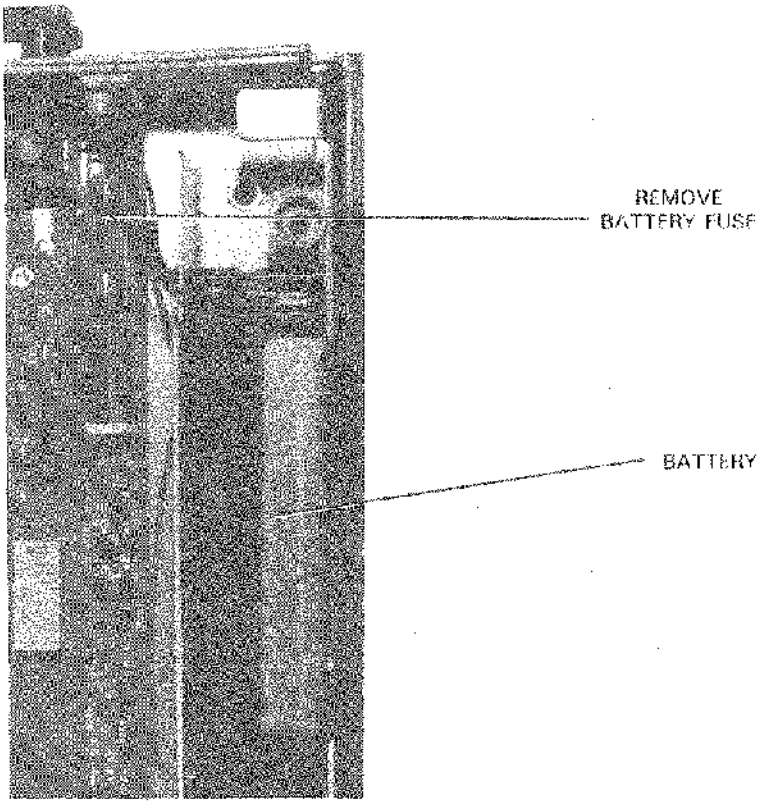
5. Remove the grey ribbon cable connector from the option in slot 1. Be very careful to lift the connector straight up from the option so as not to bend any of the pins on the connector. If the option in slot 1 is a 44462A Multiplexer option, remove the 4-wire voltmeter input cable from the motherboard.

6. Remove the four screws that hold the slot 1 option in place.

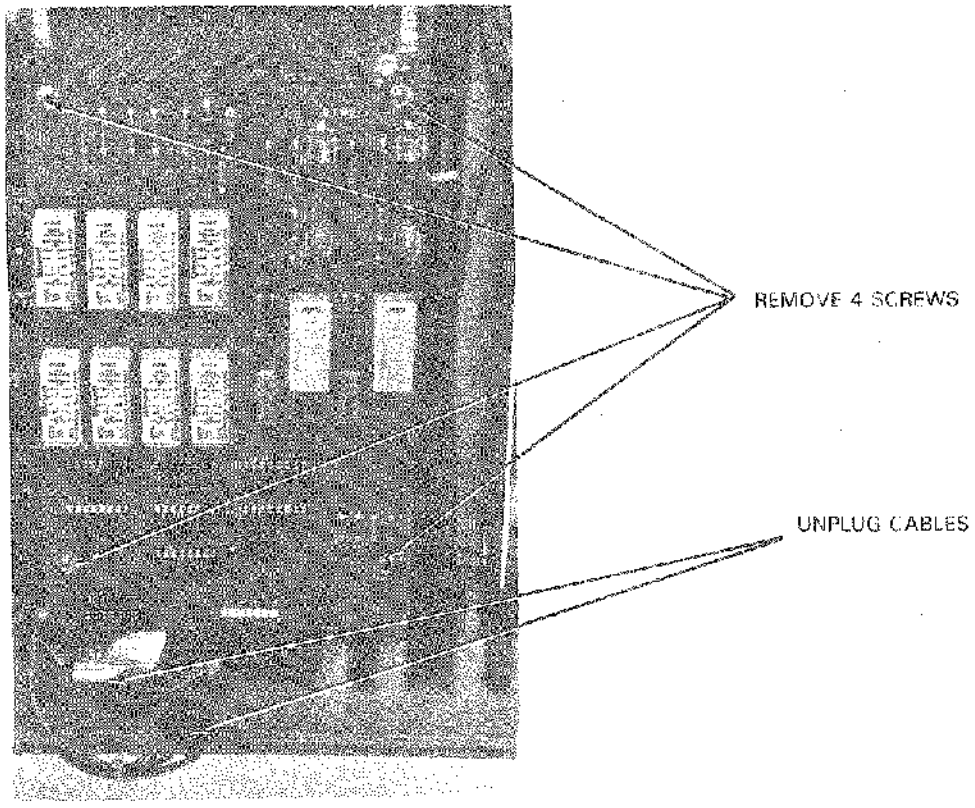
7. Remove the option from slot 1.

8. Unplug the ribbon cable connector from the option assembly in slot 0. If the option in slot 0 is a 44462A Multiplexer assembly, also remove the 4-wire voltmeter cable.

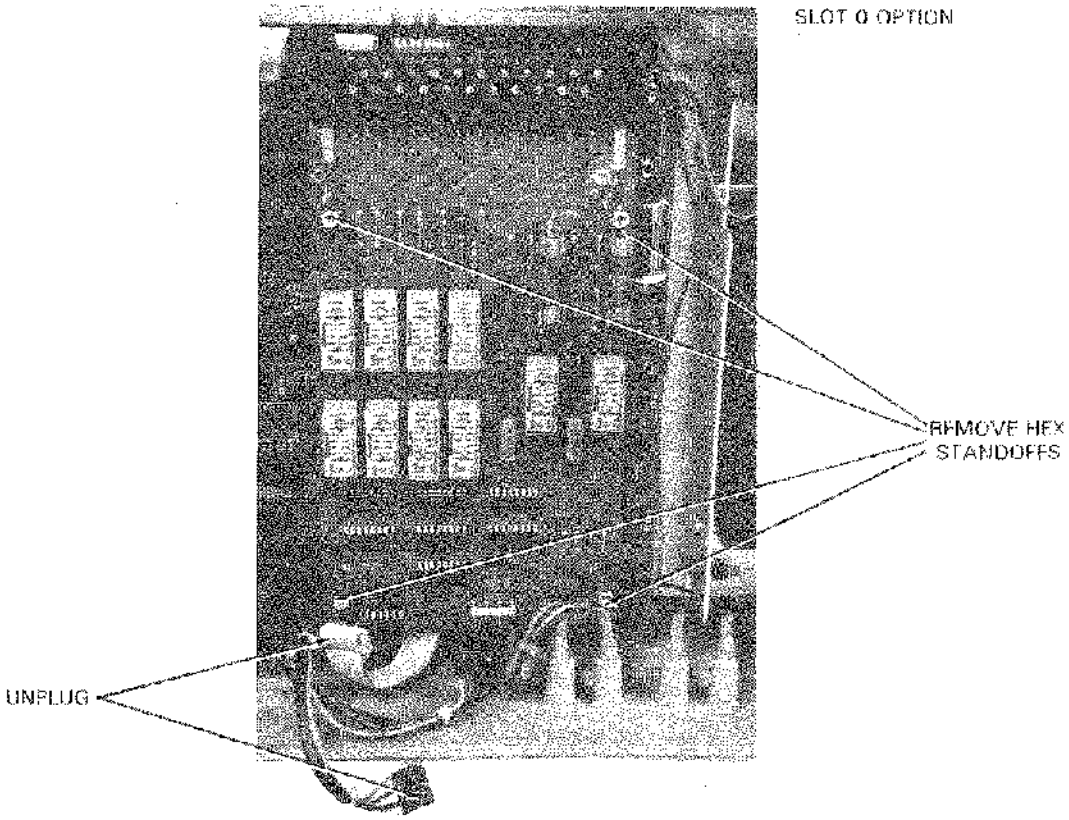
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SLOT 1 OPTION BOARD



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9. Using a 7/32" wrench, remove the four hex screw standoffs securing the option assembly. Remove the slot 0 option from the instrument.

10. Leave the bottom hex standoffs in place securing the motherboard to the chassis.

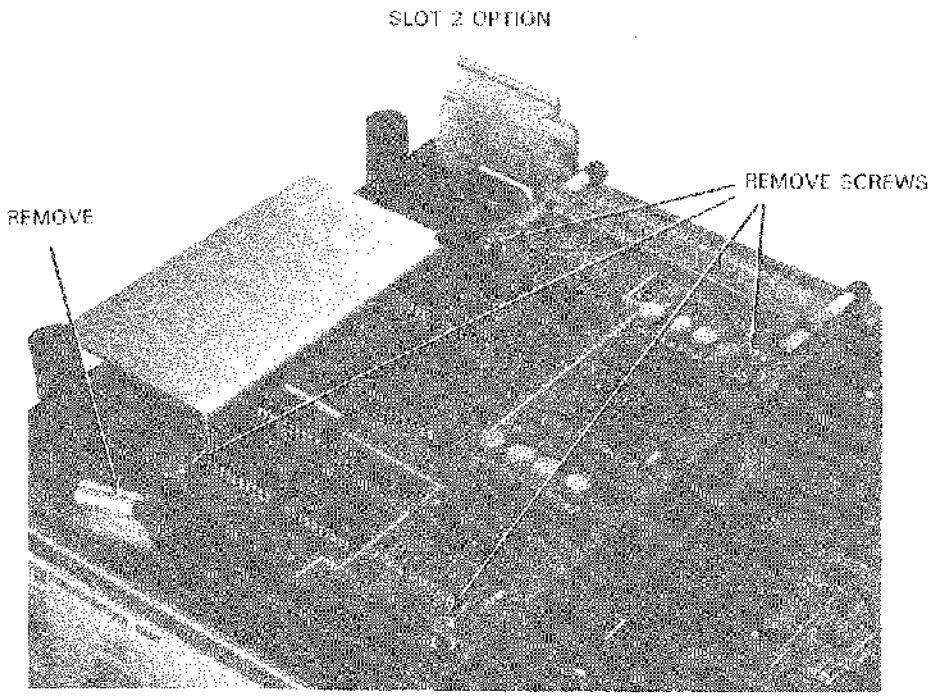
NOTE

The hex standoffs securing the motherboard to the chassis are shorter than the hex standoffs separating the two options in slots 0 and 1.

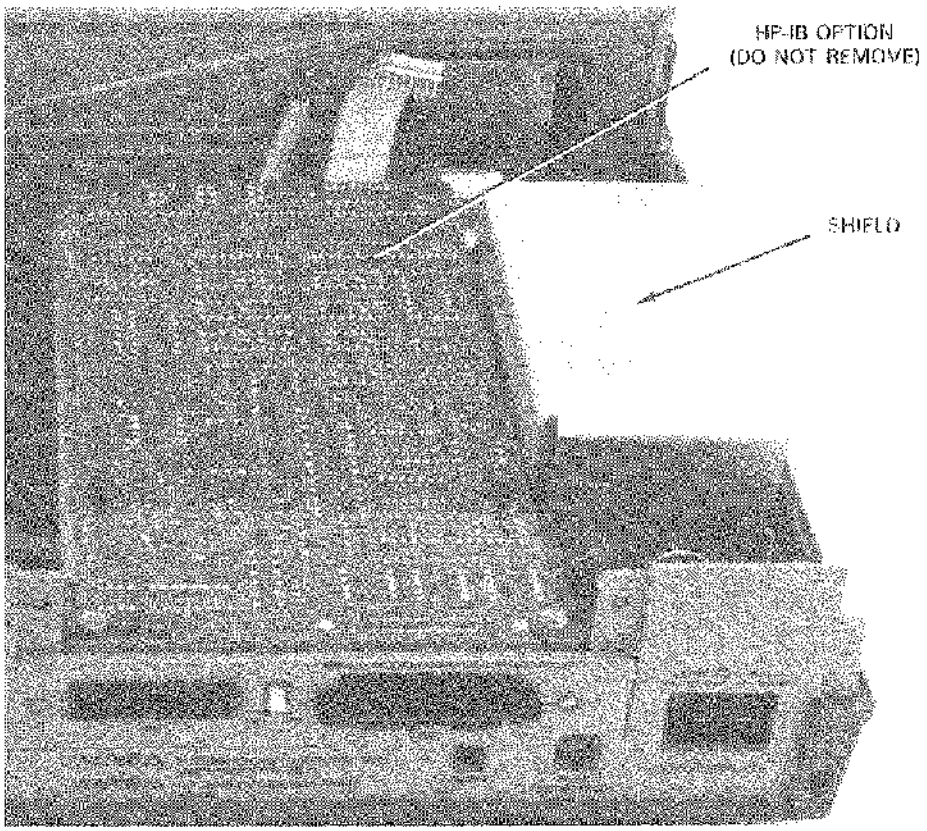
Some of the first instruments manufactured may have round standoffs that are riveted to the motherboard and round spacers between options instead of the hex screw-in standoffs. The round riveted standoffs should be firmly secured to the chassis with screws and round spacers to establish a ground connection when troubleshooting.

11. To remove the option occupying slot 2, remove the ribbon cable connector and the 4 wire voltmeter cable if present. Remove the four screws that hold the option assembly in place and remove the option.

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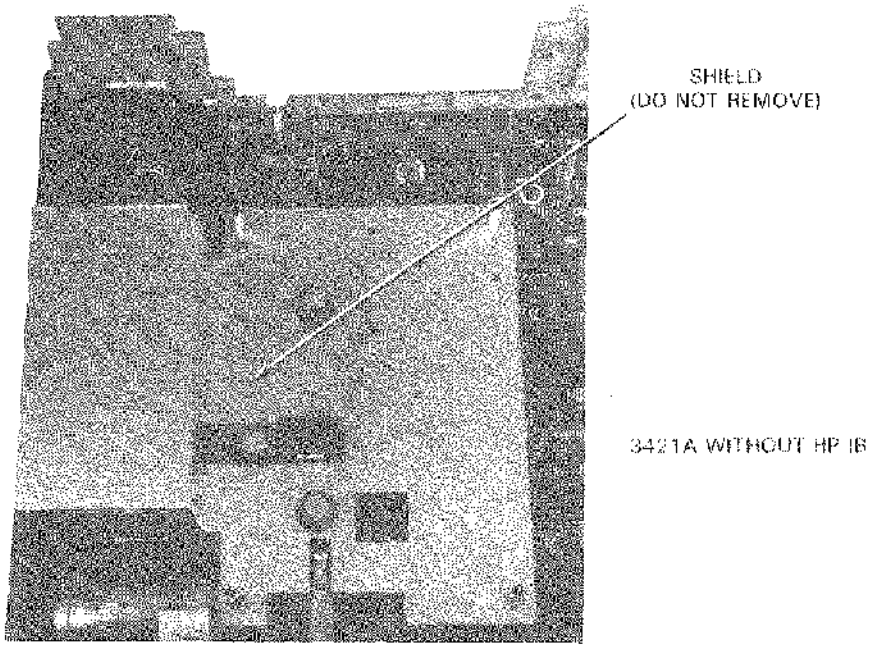


12. If the HP-IB option (option 201) is present, do not remove it. Do not remove any of the metal shields from the 3421A chassis.



3421A WITH HP-IB

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At this point, all option assemblies have been removed and are ready for reconfiguring. Refer to the specific option later in this chapter for configuration information.

Installing the Option Assemblies

Two cases need to be addressed when installing the option assemblies in the 3421A chassis. The first case assumes that the same options are being installed that were previously removed. In this case remember to install the options in the same slots they were removed from. The second case is for new options to be installed. In other words, an option that was not previously installed is now being installed. As a general rule, multiplexing assemblies should be installed in slots 0 and 1 before installing them in slot 2.

NOTE

In order to ensure the highest accuracy on all temperature measurements, the 3421A should be recalibrated after installing a 44462A Multiplexing Assembly. If the 3421A is not recalibrated with the multiplexer assembly installed, the 3421A self test will fail (uncalibrated) and the first reading returned to the calculator will be an error message.

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Before installing on option assembly in slot 2, make certain that the ribbon cable is routed around the shield standoffs as shown in the following photograph. This will prevent the ribbon cable from interferring with the front panel POWER switch. If the option 201 HP-IB assembly is installed, this cable will be below the HP-IB circuit board.

1. If your 3421A is not equipped with the HP-IB option, place the slot 2 option assembly directly on top of the bottom shield standoffs. Put the four long screws in place but do not tighten them yet. Go to step 3.

2. If your 3421A is equipped with the HP-IB option, make certain that all cables to the HP-IB option are in place and that the HP-IB circuit board is positioned component side down on top of the bottom shield standoffs. The option assembly for slot 2 is mounted component side up on top of the HP-IB circuit board. Put the four long screws in place but do tighten yet.

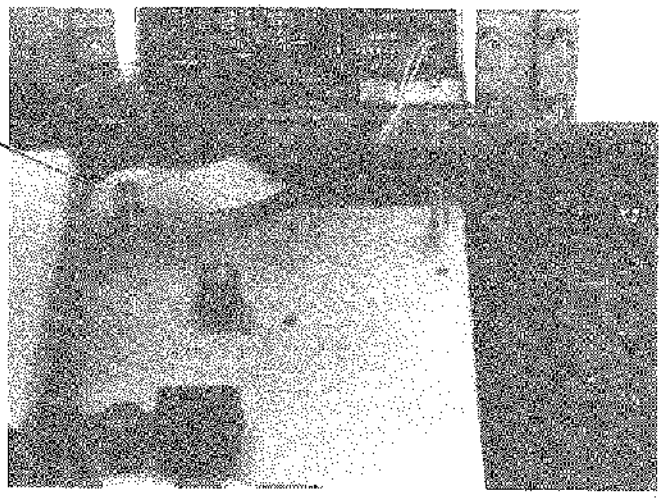
3. Plug the appropriate terminal block edge connector onto the option assembly in slot 2.

4. Re install the grey 'WARNING' safety cover onto the 3421A back panel for slot 2. Align the option assembly so that the black strain relief bar can be screwed into place. Loosely attaching one screw through the black strain relief bar will align both holes. Finally, tighten down the four screws holding the option assembly in place.

5. Plug the ribbon cable onto the option assembly in slot 2. Make sure that the red stripe on the cable is oriented to the right. If the option assembly for slot 2 is a 44462A Multiplexing Assembly, connect the 4 wire voltmeter cable to the option. This 4 wire cable should be oriented per the label on the circuit board and connected to J100 on the motherboard (grey to grey, etc.).

SLOT 2 OPTION
CABLE ROUTING

ROUTE CABLE AROUND STANDOFFS
(THIS CABLE ROUTING IS THE SAME
WHETHER HP-IB OPTION IS INSTALLED
OR NOT.)

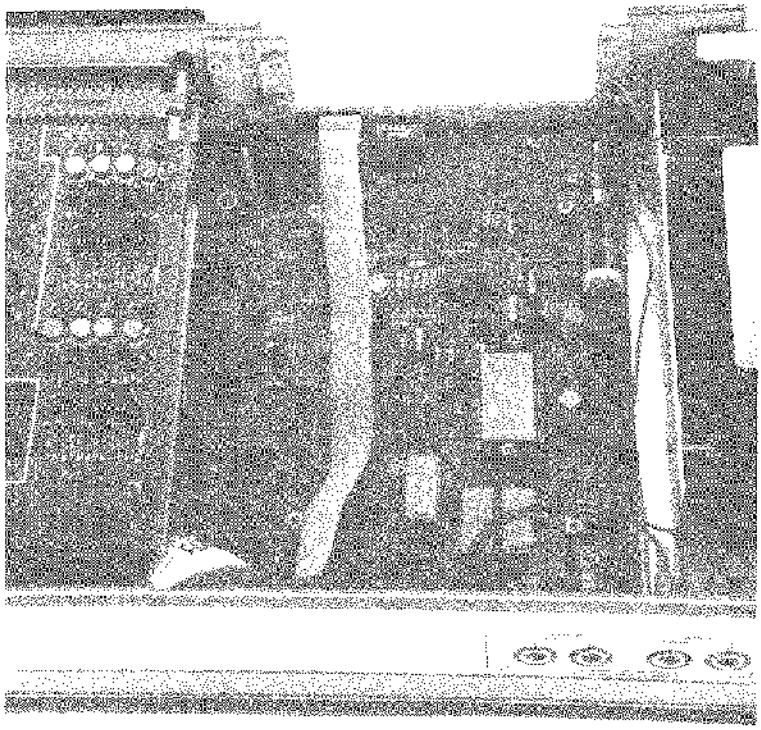


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6. To install an option assembly in slot 0, make certain that the four hex standoffs are in place in the motherboard. DO NOT OVERTIGHTEN THESE STANDOFFS. Excessive torque (>11 in/lb) may break off the screw heads.

7. Route the ribbon cable from J500 on the motherboard between standoffs. The red stripe should be oriented to the right. Make sure that it will not get pinched between a standoff and the option assembly that will be mounted in slot 0.

SLOT 0
CABLE ROUTING



8. Set the slot 0 option assembly in place, component side up. Make certain that the ribbon cable underneath is not pinched. Loosely screw in the remaining 4 hex standoffs. Do not tighten these standoffs at this time.

9. Plug the ribbon cable into the slot 0 option assembly. Make sure that the red wire is oriented to the right. If the slot 0 assembly is a 44462A Multiplexing Assembly, plug the 4-wire voltmeter cable into the option assembly. Orient the 4-wire cable per the label on the option board. The other end of this cable should be connected to J110 on the motherboard with the wires oriented per the label on the motherboard.

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10. Plug the appropriate terminal block edge connector onto the option assembly. Replace the rear panel grey 'WARNING' safety cover. Align the option assembly with the rear panel holes by installing one screw of the black strain relief bar. This will automatically align the other side.

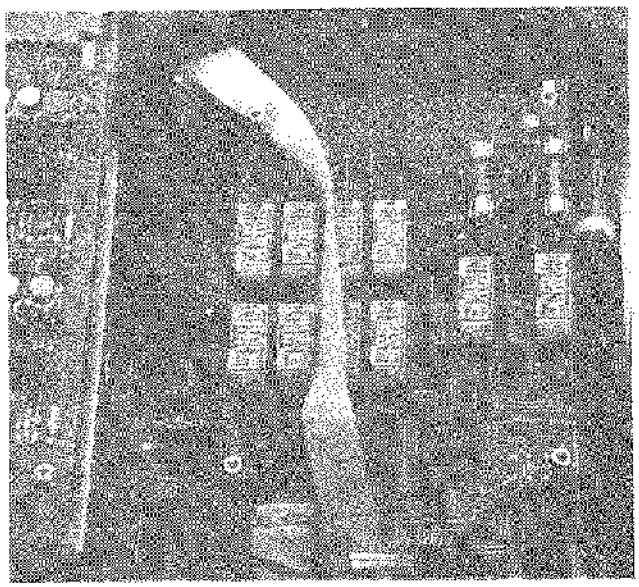
NOTE

Do not overtighten the black strain relief bar. Overtightening will cause warping of the rear panel and therefore difficulty in replacing the top cover of the 3421A. If the strain relief bar is mounted with both screws, it should be loosely attached until the top cover is installed.

11. Tighten the hex standoffs to secure the option assembly in slot 0. Do not overtighten these standoffs.

12. Route the ribbon cable from J501 across the slot 0 option assembly. Make sure the red stripe is oriented to the right.

SLOT 1
CABLE ROUTING



13. Set the option assembly for slot 1 in place. Make sure that the ribbon cable is not pinched between the standoffs and the assembly. Loosely screw the four screws to secure the option assembly in place. Do not tighten these screws yet.

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14. Plug the ribbon cable into the slot 1 option asembly making sure the red stripe is oriented to the right. If this assembly is a 44462A Multiplexing Assembly, connect the 4-wire voltmeter cable to the option. This 4-wire cable connects to J120 on the motherboard. Orient the cable as per the labels on the motherboard and the option assembly.

15. Plug the appropriate terminal block edge connector onto the slot 1 option assembly.

16. Replace the rear panel 'WARNING' safety cover for slot 1.

17. Align the option assembly with the rear panel holes and loosely screw on the black strain relief bar.

18. Tighten down the four screws securing the slot 1 option.

To replace the top cover, first make sure the main battery fuse has been replaced. Then, locate the six plastic standoffs and place them over the six cabinet screws. Make sure that the end with the small hole is up and the large hole is down.

Set the 3421A flat on the workbench. Make certain that the bail handles on the front feet are collapsed. Align the top cover and lower it in place. Be sure the guiding grooves are properly engaging the front and rear panels. If the grooves are properly engaged but the top cover will not lower into place properly, one of the plastic standoffs is probably out of alignment. To correct this, move the top cover back and forth (left and right) until the standoffs align properly.

Finally, once the top cover is in place, hold the two halves of the case together and turn the instrument upside down. Tighten the six bottom screws.

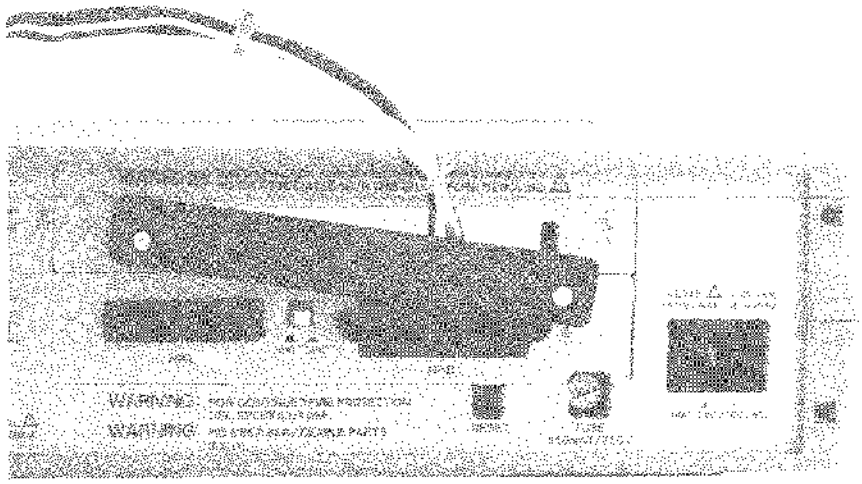
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Strain Relief

Some strain relief is provided by the 3421A for cables coming from the external transducers to the option assemblies. This strain relief is in the form of a two piece cover. The first piece is the black strain relief bar. It presses the wires against a piece of foam. The second piece is the grey "WARNING" cover.

The photograph below shows several wires coming out of the terminal blocks and through the strain relief. Be sure to leave a small loop in the wire to avoid stress in the terminal block connection. When installing the black strain relief bar, attach one end with the bar held down and away from the instrument so it doesn't bear on the foam. Then rotate the bar up and connect the other end.

To protect wires smaller than 22AWG it is recommended that these wires be bundled together starting no more than 4" from the back of the 3421A. Failure to do so may result in the wires breaking at the strain relief. To illustrate the need for this, a 26 AWG wire can survive only about 7 to 8 pounds of tension before breaking. A bundle of 10, however, could survive up to 70 pounds of tension.



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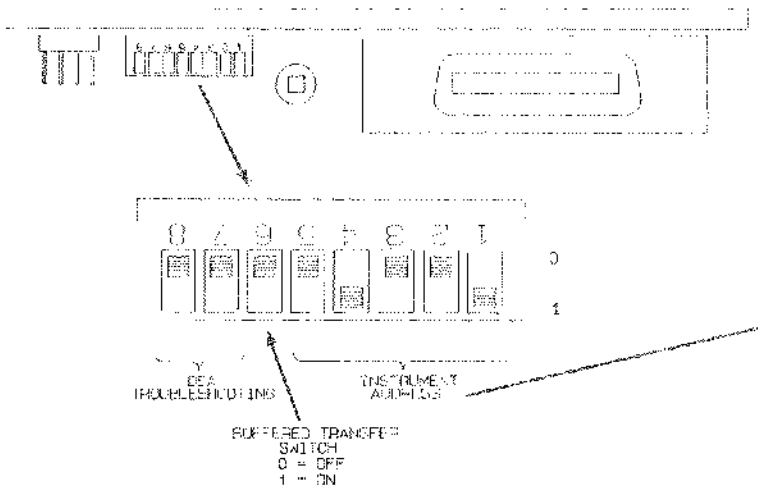
HP-IB

The Option 201 HP-IB Assembly has a set of eight switches near the back panel. These switches are accessible by removing the grey access cover. Note that the two nuts on the HP-IB connector will need to be removed.

HP-IB Switches

Option 201 for the 3421A is an HP-IB interface. This option allows the 3421A to communicate to computers via either the HP-IB interface or the HP IL interface but not both simultaneously. The option assembly is mounted circuit side down in the 3421A case and has a set of eight switches near the back panel. These switches are accessible by removing the grey access cover.

The HP-IB address of the 3421A is determined by the setting of the five right-most switches. These switches are read and displayed at power-on by the 3421A HP-IB processor to determine the HP-IB address. The 3421A Option 201 normally leaves the factory with the address switches set to decimal; code "09". The corresponding ASCII code is a Listen address code of "I" and a Talk address code of "I". Refer to the following figure for setting the address switches for other addresses.



Address	Switch Segment 5	4	3	2	1
00	0	0	0	0	0
01	0	0	0	0	1
02	0	0	0	1	0
03	0	0	0	1	1
04	0	0	1	0	0
05	0	0	1	0	1
06	0	0	1	1	0
07	0	0	1	1	1
08	0	1	0	0	0
09	0	1	0	0	1
10	0	1	0	1	0
11	0	1	0	1	1
12	0	1	1	0	0
13	0	1	1	0	1
14	0	1	1	1	0
15	0	1	1	1	1
16	1	0	0	0	0
17	1	0	0	0	1
18	1	0	0	1	0
19	1	0	0	1	1
20	1	0	1	0	0
21	1	0	1	0	1
22	1	0	1	1	0
23	1	0	1	1	1
24	1	1	0	0	0
25	1	1	0	0	1
26	1	1	0	1	0
27	1	1	0	1	1
28	1	1	1	0	0
29	1	1	1	0	1
30	1	1	1	1	0

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The next switch (switch 6) is the Buffered Transfer Enable switch. The use of this switch is described in Chapter 3. As a general rule, this switch should be left in the up position unless the computer will be performing some task while the 3421A is making measurements.

The last two switches are used when servicing the HP-IB circuit board. For normal operation these switches must be in the up position.

Installing the 44462A Multiplexer Assembly

WARNING

The 3421A uses latching relays on the multiplexer assembly (option 020, 021, and 022) and on the mainframe. The state of these relays can only be altered under program control. This is an advantage in the sense that, under most conditions of failure, the relays will remain in whatever state your program has set them. However, in case of power or equipment failure, any application requiring a failsafe method of ensuring that the circuits under control are in a known state must be provided by the installer.

WARNING

In case of a component failure or programming error, any voltage that is input to a multiplexer assembly may be present on any other terminal of any installed multiplexer assembly as well as the 3421A front panel terminals. Likewise, any voltage that is input to the 3421A front panel terminals may be present on any other terminal of any installed multiplexer assembly.

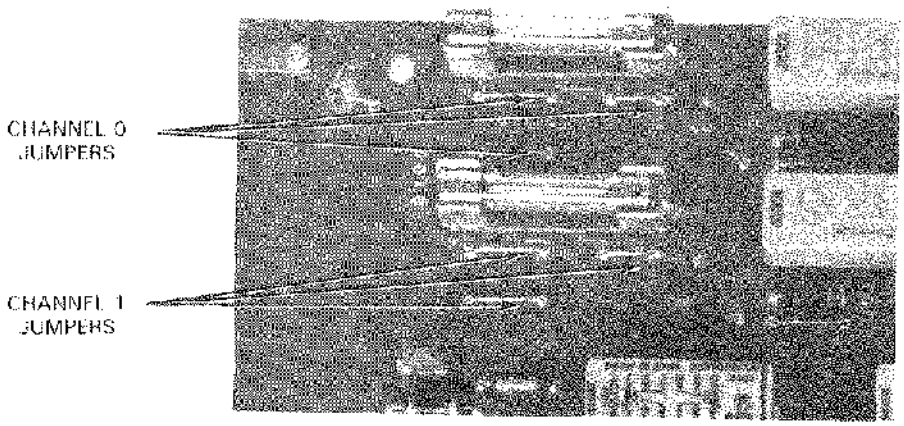
Installation procedures for the 44462A 10 Channel Multiplexer Assembly are straight forward. However, pay attention to the many jumpers on the assembly. The configuring of these jumpers is what will be considered next.

These jumpers can be divided into four groups. The first group is used to configure channels 0 and 1 as either actuators or as multiplexers. The second group of jumpers are used by the 3421A to determine which channels are configured as actuators and which are multiplexers. To make 4-wire ohms measurements requires removing two jumpers and replacing two others; these four belong to the third set of jumpers. Finally, the fourth set are used to install attenuators in the signal paths.

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Actuator/Multiplexer Jumpers

Channels 0 and 1 on each mulitplexer assembly can be configured as either actuators or as multiplexers. Several jumpers are provided on each channel for this conversion. The photograph below shows where these jumpers are located.



The diagram and chart below show which jumpers need to be in place for the channels to be configured as actuators and which jumpers for multiplexers. Note, the 44462A assembly is factory preset with channels 0 and 1 configured as actuators.

The following diagram and chart shows which jumpers need to be in place for channels 0 and 1 to be configured as actuators and which jumpers need to be in place for channels 0 and 1 to be configured as multiplexers. When a 10 Channel Multiplexer Assembly is ordered factory installed, it can have one of three different configurations (Option 020, 021, or 022). Option 020 has channels 0 and 1 configured as actuators and channels 2-9 configured as multiplexers. Option 021 has channel 0 configured as an actuator and channels 1-9 configured as multiplexers. Option 022 has all ten channels configured as multiplexers.

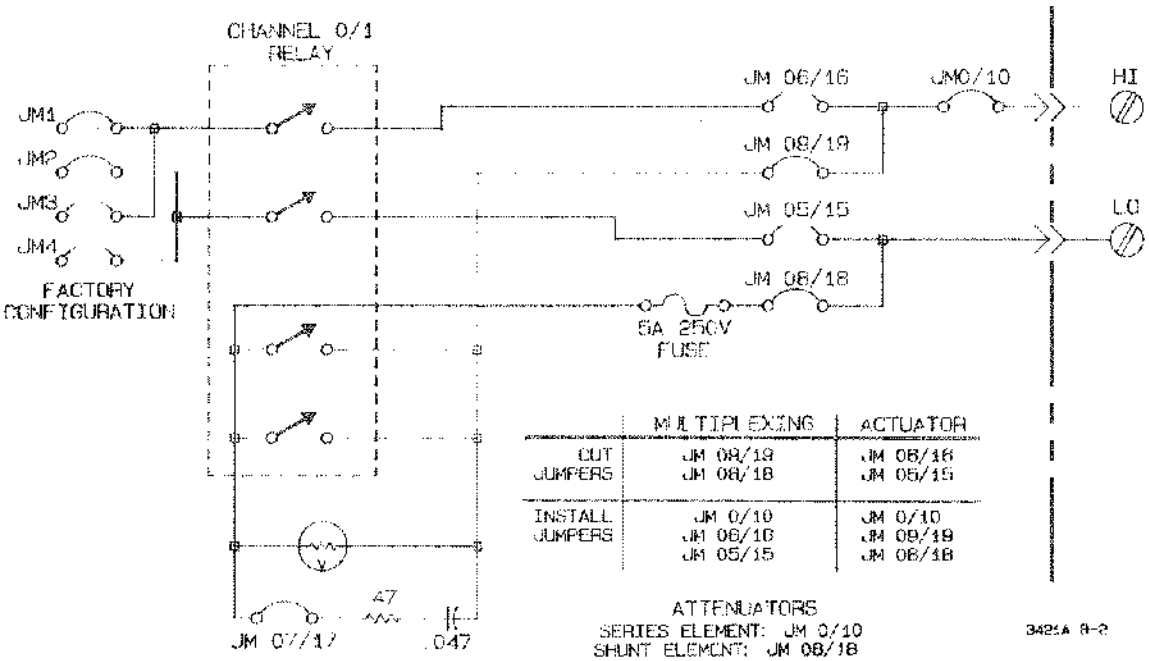
When a 10 Channel Multiplexer Assembly is ordered for field installation (44462A), channels 0 and 1 will be configured as actuators and channels 2-9 will be configured as multiplexers.

Regardless of how a 10 Channel Multiplexer Assembly is ordered, the built-in 10:1 divider on channel 2 is bypassed (i.e., jumper in the "OUT" position) at the factory. However, this was not the case on early versions of a multiplexer assembly (see the following note).

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NOTE

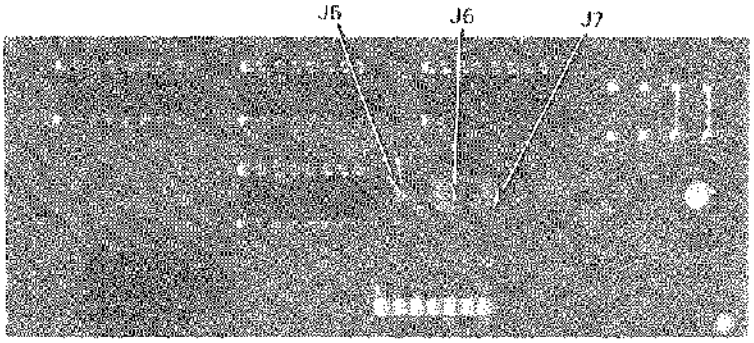
Factory installed Option 020 and field installed Kit 44462A have been available since the introduction of the 3421A. Early versions of Option 020 and Kit 44462A had the same channel configuration as current options, except that they also had the built-in 10:1 divider jumper of channel 2 in place (i.e., in the "IN" position). The 10:1 divider has since been bypassed at the factory on all options (i.e., jumper in the "OUT" position). Option 021 and 022 were introduced so that the instrument could be ordered with a factory configuration to meet most applications.



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Configuration Identification Jumpers

The configuration jumpers, the second set, are located as shown in the photograph below. These jumpers are used to indicate how the assembly is configured and must be set along with any other re configuring. If these jumpers are not properly configured, an error may result. For example, if you have channel 1 configured as a multiplexer, but the configuration jumpers show it as an actuator, an error will result when you ask for a measurement from that channel; i.e., DCV1.



These jumpers set a code that is sent to the 3421A microprocessor to let it know the type of board as well as its configuration. The possible combinations for the jumpers are:

J5	J6	J7	Configuration/Type
0	0	0	No actuators, all 10 channels are configured as multiplexers.
0	0	1	Channel 0 is an actuator, all others are multiplexers.
0	1	0	Channel 1 is an actuator, channels 0 and 2-9 are multiplexers.
0	1	1	Channels 0 and 1 are actuators, all other channels are multiplexers.

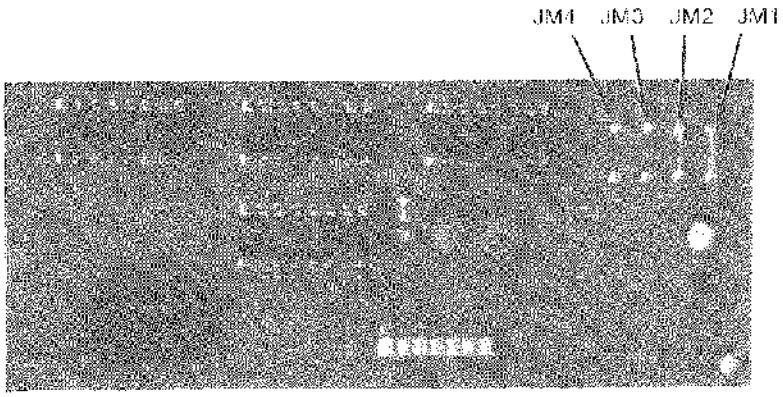
CAUTION

Your 44462A Multiplexing Assembly may or may not be equipped with a jumper J5. If it is equipped with J5, it MUST remain in the '0' position. Moving J5 to the '1' position will cause the 3421A to think that the assembly is either non-existent or that it is a 44465A Digital I/O Assembly. This can cause substantial confusion when attempting to close channels or make measurements.

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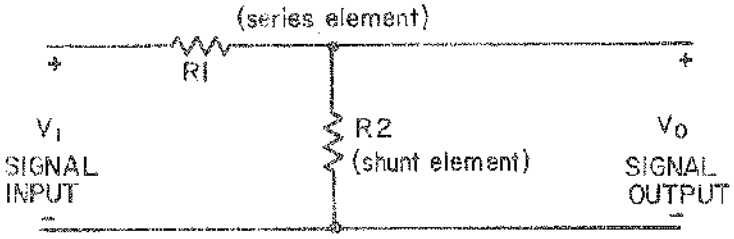
2- and 4-wire Ohms Measurements

There are four jumpers located near the rear of the assembly. See the photograph below. For any measurements except 4-wire ohms measurements, jumpers JM3 and JM4 should be removed. To make 4-wire ohms measurements, two 44462A assemblies are required. One assembly will have jumpers JM3 and JM4 removed. This assembly serves as the ohms current source multiplexer. The second assembly will have jumpers JM3 and JM4 installed but jumpers JM1 and JM2 removed. This assembly serves as the sense multiplexer. Refer to the diagram below.



Attenuators

Provisions are made on the 44462A circuit board for attenuators to be installed on all but two channels (channels 8 and 9). An attenuator is composed of two resistors that act as a voltage divider. Consider the following diagram.

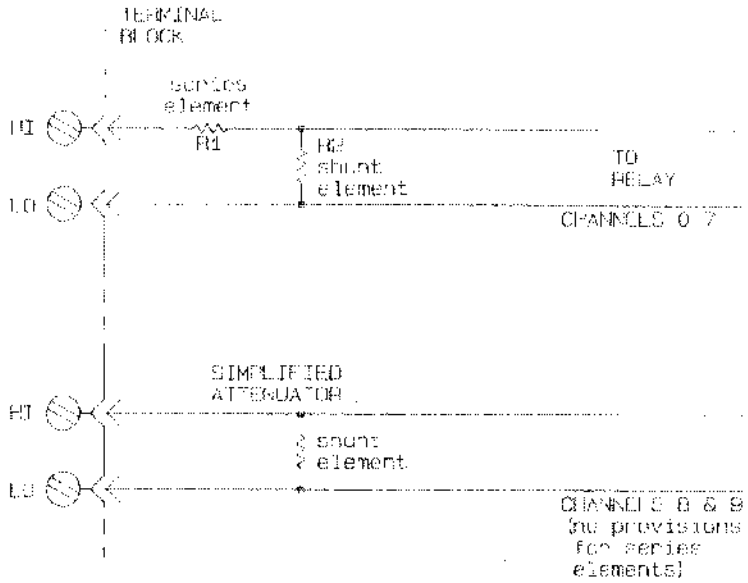


$$V_O = V_I * (R2/(R1+R2))$$

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Channel 2 has a built-in, jumper selectable, 10:1 attenuator. This attenuator can be removed by moving jumper J8 from the 'IN' position to the 'OUT' position. This attenuator has an input impedance of 1 Mohm (R1 + R2) to prevent loading of the signal source.

Channels 0, 1 (when configured as multiplexers) and channel 3 through 7 can all have attenuators built into their respective signal paths. The following diagrams show how this can be done. A package of seven pairs of resistor (-hp- part number 44469A) are available for use as attenuators. These resistors are the same values as those used in channel 2.



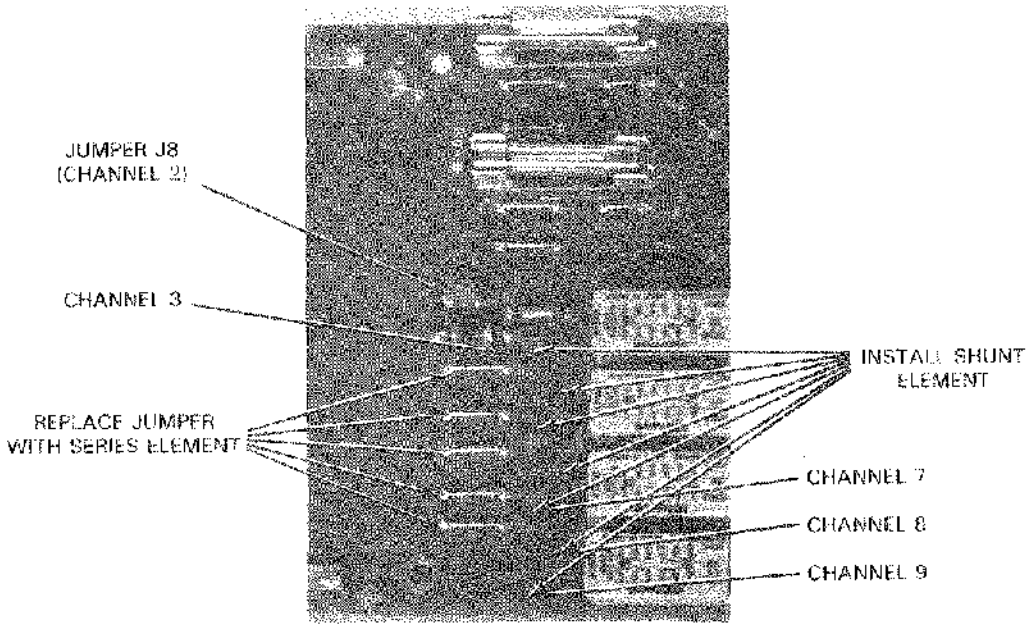
$$\text{INPUT VOLTAGE} = \text{MEASURED VOLTAGE} \times \left(\frac{R1+R2}{R2}\right)$$

NOTE:
USE JM 0/10 FOR SERIES ELEMENT AND JM 8/18 FOR SHUNT ELEMENT ON CHANNELS 0 AND 1. JUMPER JM 09/19 HAS TO BE IN PLACE AS WELL AS JM 05/15 AND JM 06/16. REMOVE JM 02/17.

3421-8-4

Channels 8 and 9 can only have shunt elements built across their signal paths. An example of where this would be useful is with 4 - 20 mA transducers. A 50 Ohm resistor, ± .1%, .5 watts (-hp- part number 0699-0064) can be placed across the signal path. The resultant voltage drop (transducer current through the resistor) can be measured by the 3421A internal voltmeter. Thus, the 50 Ohm resistor converts the 4 – 20 mA signal to 0.2 – 1 volt signal.

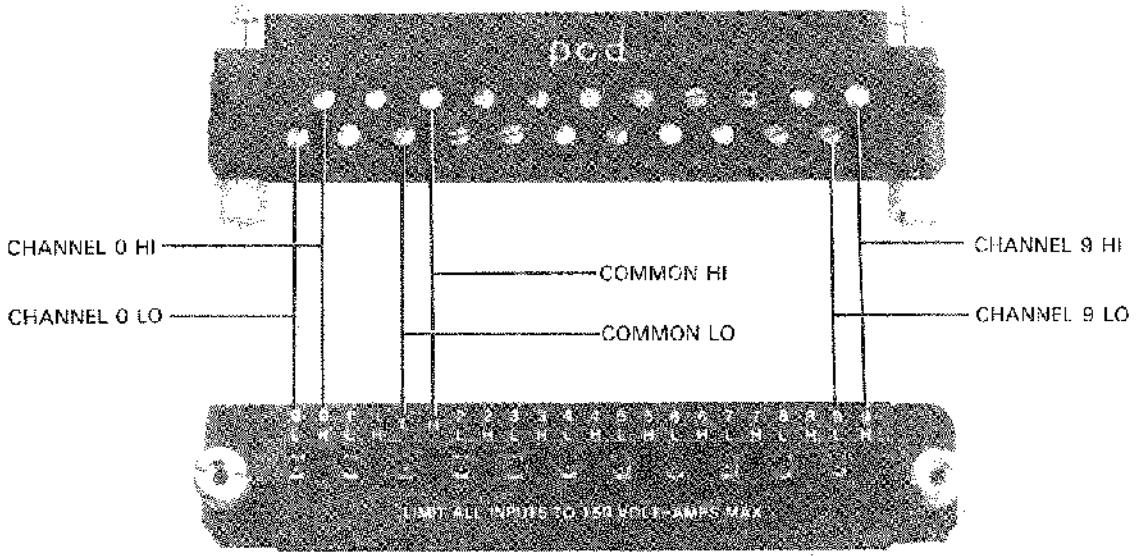
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The Terminal Block Edge Connector

The following photograph shows the channel connection sequence for the terminal block. Extra terminal blocks are available under the -hp- part number: 44463A.

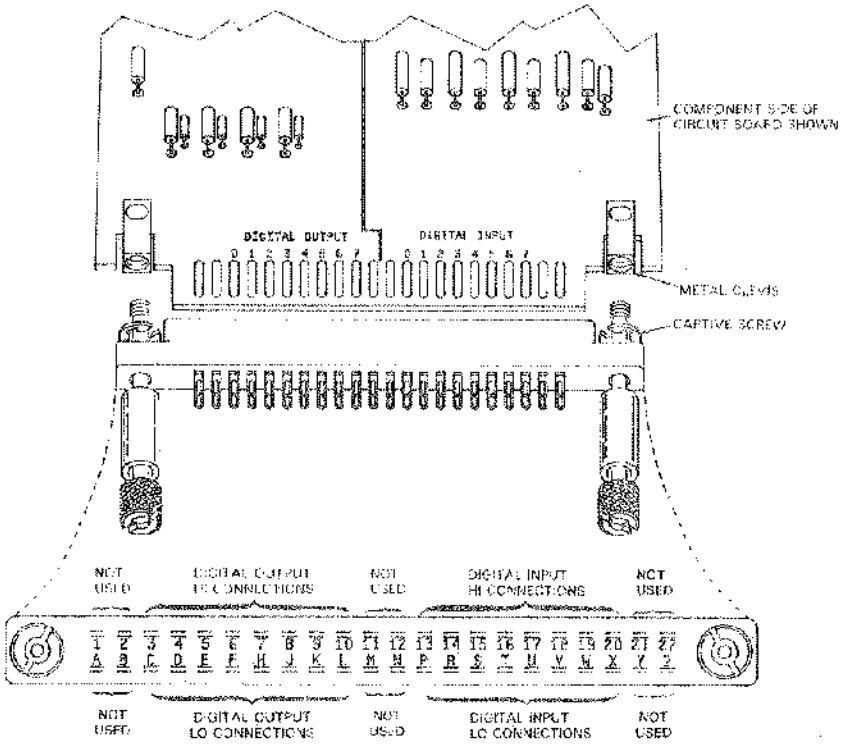
When installing the terminal block on the multiplexer assembly, make sure the terminal block is firmly seated and square against the multiplexer circuit board. Hand tighten the captive screws into the clevis' on the circuit board. Remember, any wires smaller than 18 guage should be bundled together starting ideally no more than 4'' from the terminal block.



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Installing the 44465A Digital I/O Assembly

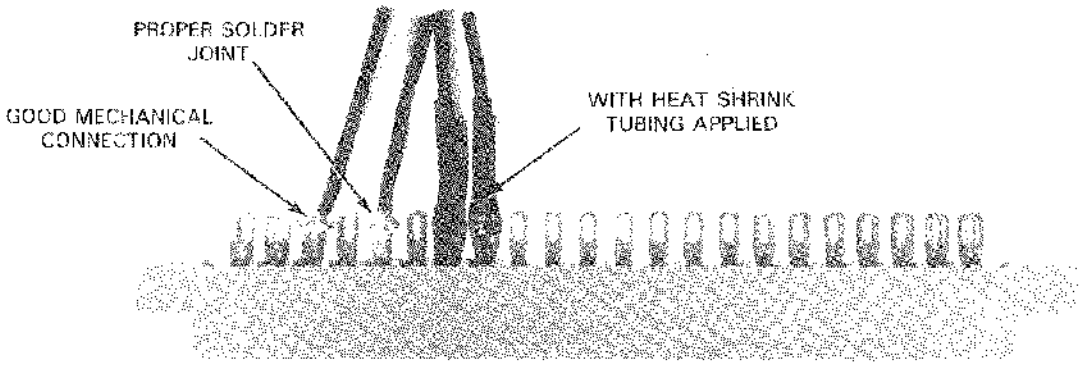
Because there are no jumpers to be configured on the Digital I/O assembly, we will concern ourselves in this section with the wiring of the terminal block edge connector. The channel connection sequence for the terminal block is shown in the photograph below. Extra terminal blocks are available using the -hp- part number: 44466A.



The Terminal Block Edge Connector

The wires to the external devices must be soldered to the lugs on the terminal block. Use care when soldering to the lugs to prevent breaking them off. Follow standard soldering practice such as making a good mechanical connection before soldering. Do not use too much solder. Use only rosin core solder, NEVER use acid core solder. After the solder connections have been made, cover each joint with heat shrinkable tubing to act as a strain relief and prevent adjacent wires from shorting to each other.

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Cleaning

Clean handling techniques should be used when configuring the option assemblies. This is especially true of the 44462A Multiplexing Assembly where contamination will decrease the board impedance. If measurements are to be made under high humidity (>80%) and high temperature (>90° F) environmental conditions, the circuit board and edge connector should be cleaned. Also, if very high resistance measurements, or voltage measurements in high impedance circuits the terminal block edge connector must be cleaned. The following procedures can be used to clean the circuit boards after configuration.

1. Remove all source of power from the option assemblies. Then, remove the circuit board from the 3421A.

2. Wash the circuit board assembly with isopropyl alcohol.

3. Rinse the board thoroughly with de-ionized water.

4. Dry the circuit board completely before re-installing it in the 3421A.

5. The terminal block edge connector should be cleaned using the same procedure.

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CHAPTER 9
44464A
Breadboard Option
Option 040

Introduction

This chapter provides the technical information necessary for the design engineer or electronic technician to use the 44464A breadboard assembly with the 3421A Data Acquisition Control Unit. This chapter is NOT intended for use by non-technical personnel.

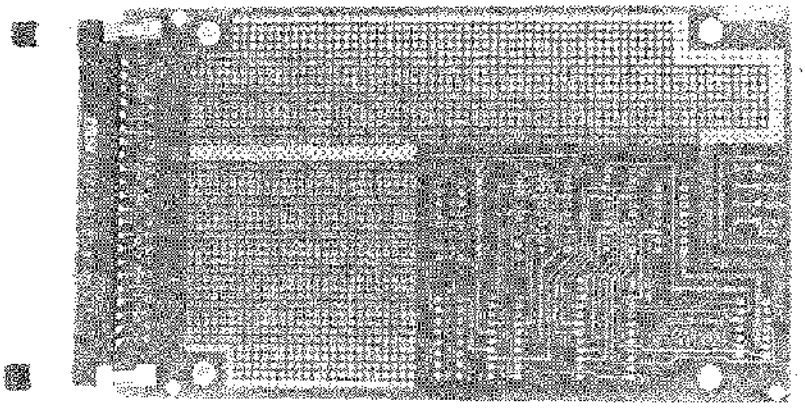
At the end of this chapter are two pages, each showing a full size view of the front and back of the 44464A Breadboard assembly. These pages are provided to assist you in designing and laying out your circuits. You may want to tear one sheet out and duplicate for future use.

The 44464A Breadboard consists of two areas:

1. A breadboarding area which includes two power supplies, ±5 volts and the battery voltage; a ground bus, which is tied to the 3421A front panel LO terminal, a 22 pin edge connector, and provisions for connecting to the 3421A internal voltmeter/counter.

2. Built-in design (you provide components) for providing an 8-bit digital input port and an 8-bit output port. The two ports are controlled by the same commands that control the 44465A Digital I/O assembly. These commands will be discussed later in the chapter. The two ports are referenced to the 3421A front panel LO terminal. Therefore, care must be taken if isolation is needed.

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Before You Begin

Prior to designing and building any circuit on the breadboard, familiarize yourself with the signals available. Read through this entire chapter carefully. The following paragraphs describe certain hints and precautions which, if carefully observed, will cause your circuit and the 3421A to perform more reliably.

Voltmeter Input Connections

In the lower left corner of the 44464A assembly are four pins labeled: 4WL, 4WH, DCL, and DCH. These pins are for making connections to the 3421A internal voltmeter or counter. The DCL (voltmeter Low) and DCH (voltmeter High) pins are used for AC or DC voltage and 2-wire resistance measurements. They also connect to the internal counter. Make certain that no more than 300 volts (peak) is ever applied to these terminals.

The 4WL and 4WH pins are used when making 4-wire resistance measurements. They are to be used for this purpose only.

WARNING

Damage to the 3421A or external devices may result if voltage inputs are made through the front panel terminals and/or the 44462A Multiplexer and/or the 44464A breadboard DCL and DCH connections simultaneously. Under no circumstances should a voltage be input through the front panel terminals or the multiplexer relays (with a relay closed) at the same time a voltage is being input through the breadboard assembly to the voltmeter.

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Parts Supplied

The following is a list of all parts supplied with the 44464A Breadboard assembly.

Quantity	-hp- Part Number	Description
1	1200-0854	14 Pin DIP Socket
1	44464-66505	Bread Board Circuit Board
1	1251-0233	Circuit Board Edge Connector
1	1251-7825	4-Terminal, Right Angle Connector
1	8120-3727	4-Conductor Cable Assembly
1	8120-3678	14-Conductor, Flat Ribbon Cable
1	4040-2133	Strain Relief
1	4208-0416	Adhesive Backed Foam for Strain Relief. 90.1 X 9.9 mm
2	2190-0879	Washer
2	0510-0952	E-type Screw Retainer
2	1390-0624	Captive screw, 3.0 X 36 (Metric)
2	1390-0630	Captive Screw, 3.0 x 16 (Metric)
2	3050-0716	Flat Washer
2	0380-0008	Spacer

Parts Not Supplied

Parts required but not supplied for the 8-bit input/output port are listed below. The location and usage of these parts will be described later in this chapter.

Quantity	-hp- Part Number	Description
1	1820-1746	CMOS Hex Buffer Integrated Circuit, such as CD4049, or MC14049UBCP
1	1820-2232	CMOS 8-Stage Statis Bidirectional Parallel/Serial Input/Output Bus Register such as CD4034 or MC14034BCP
1	1820-2215	CMOS Tri-state, Octal D-Type Latch such as MM74C373N
1	1820-2538	CMOS Tri-state, Octal Buffer & Line Driver with Inverting Outputs such as MM74C240N
1	1820-2537	CMOS Tri-state Octal Buffer & Line Driver such as MM74C244N

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Power Supply Limitations

The following power supply limitations must be adhered to:

Supply	Available Current	Comments
+5V	≤35 mA	Current Regulated Supply
+6V Batt.	≤150 mA	Internally Fuse Protected

Note: all power supplies are referenced to the LO input terminal on the front panel.

Battery Charging Restraints While the 3421A is Operating:

If $I_{|5v} + I_{vb} \leq 20$ mA then there is no change in the battery charging specification.

If 20 mA $\leq (I_{|5v} + I_{vb}) \leq$ maximum specified above, then battery will still charge but it will take substantially longer; up to 3 days for a full charge.

Power Supply Filtering

It is recommended that bypass and filter capacitors always be used between the +5V supply and ground. A good rule to follow is to use one 1μF tantalum filter capacitor and two .01 μF ceramic bypass capacitors for every eight (or less) IC's.

Thermal Gradients

Remember that thermal gradients caused by large power dissipations can cause errors in thermocouple temperature measurements on 44462A assemblies. Therefore, power dissipation must be kept to under 1 watt on the breadboard assembly.

Switching Inductive Loads

If your application involves switching inductive loads, arc suppression circuits may be required. These suppression circuits serve to minimize radio frequency radiation (RFI), voltage and current surges, and relay contact breakdown.

The following simplified design equations for an RC arc suppression network, will usually provide adequate protection. However, since the R and C values involve parameters difficult to determine precisely, such as the type of relay used, wiring

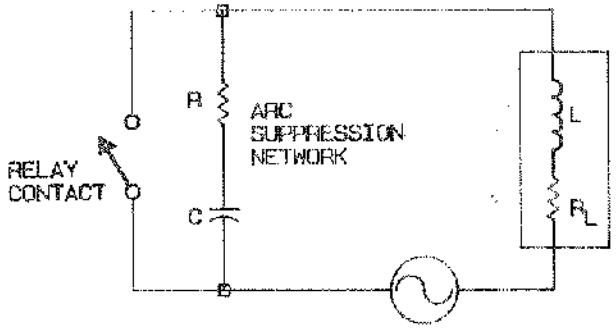
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capacitance, etc., tests to determine the effectiveness in actual circuits should be performed. The design equations are only guidelines and are not warranted.

a. R is selected as a compromise between two values. The minimum value for R is determined by the maximum accepable relay contact current. Thus, the minimum value for R is Vp/I, where Vp is the peak value of the supply voltage and I is the relay current. The maximum value of R is usually equal to the load resistance, Rl. So, the limits on R are: $Vp/I < R > Rl$.

b. To compute the value of C, use the equation: $C \geq (Io/300)^2) \times L$ where L is the load inductance, Io is the current through L just before the relay opens, and C is the total circuit capacitance.

To minimize interference caused by high voltage switching, maintain maximum isolation between the switched voltages and the 3421A logic circuits. Choose relays that have a low contact to coil capacitance.



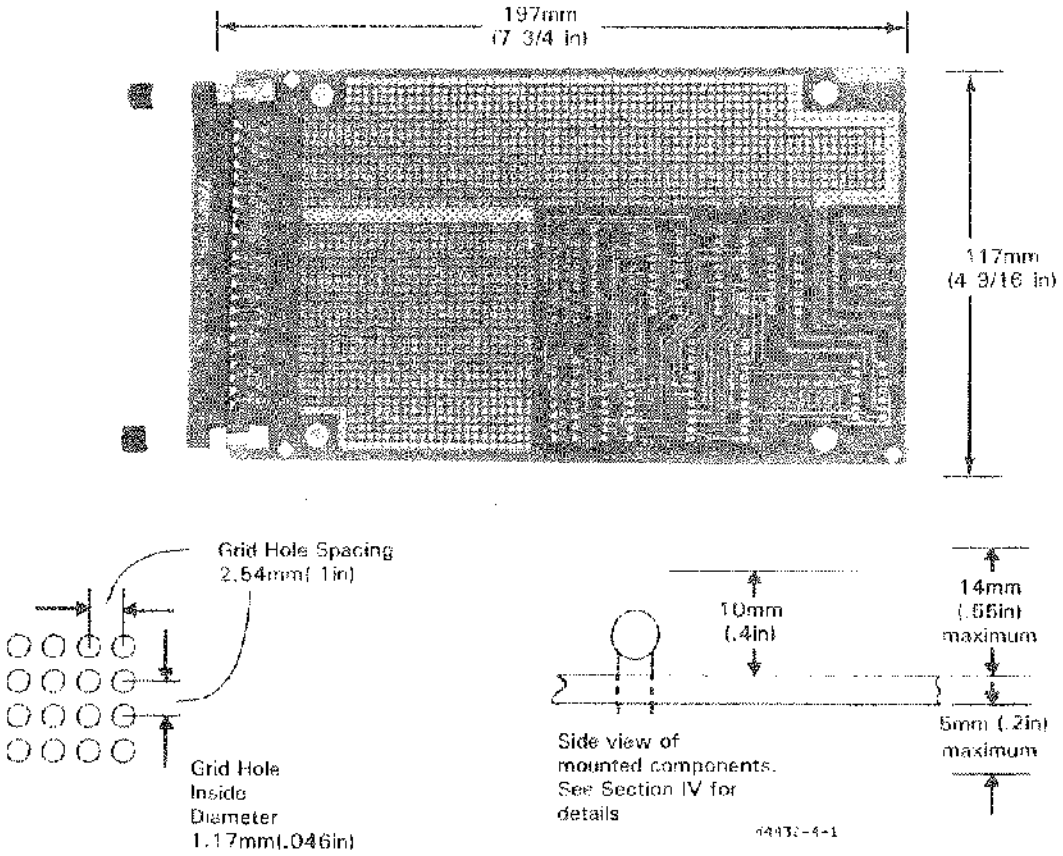
Radiated Noise

To ensure compliance with applicable standards for Electromagnetic Interference, circuits should be constructed using good RF practice. This means shielding connected to a good earth ground, etc.

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The Circuit Board

The figure below shows the dimensions of the circuit board and explains the component height/protrusion restrictions.



Voltage and Resistance Measurements

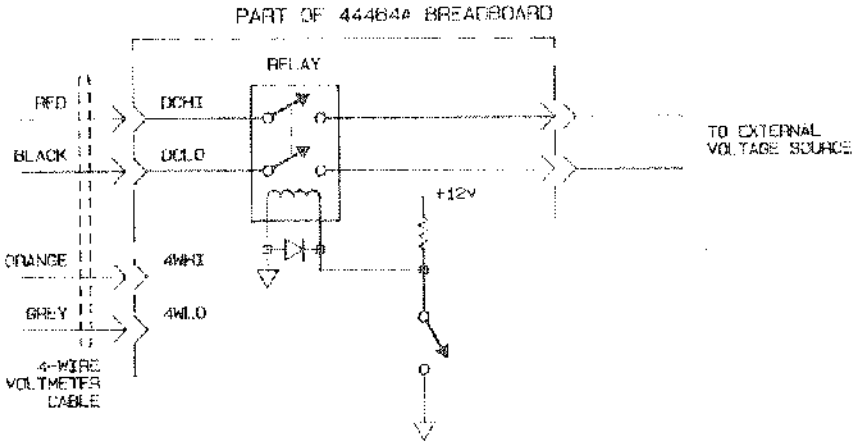
As mentioned earlier, connections to the 3421A internal voltmeter are made through the DCL and DCH pins on the 44464A breadboard assembly. Keep in mind that any voltage appearing on these pins will also appear on the 3421A front panel and on any 44462A closed channel in the 3421A. Conversely, any voltage being input through the 3421A front panel terminals or through the multiplexer assembly will appear on the breadboard DCL and DCH pins. Therefore, any voltages to be measured from the breadboard assembly should be isolated, preferably with a relay. The 8-bit digital output port can be used to control the relay.

To make a DC, AC or 2-wire resistance measurement from the breadboard, three steps should be taken. First, make certain that all relays on 44462A multiplexer assemblies are open. This can be done by executing the OPN command.

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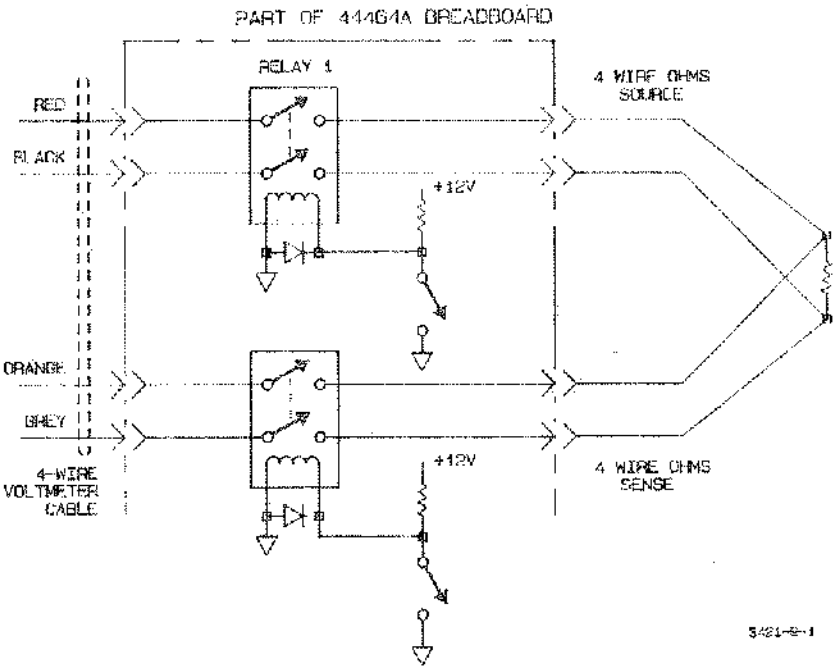
Second, close the relay on the breadboard assembly. This can be done with the BIT command, described later in this chapter.

Finally, execute DCV, ACV or TWO, whichever is appropriate for the measurement you want to make. With no channel list following the command, the measurement is made from the breadboard assembly. This process is shown in the following example.



4-Wire Resistance Measurements

Essentially, 4-wire resistance measurements follow the same constraints outlined above for voltage and 2-wire resistance measurements. The major difference is that the 4WL and 4WH pins are used instead of the INPUT pins. The figure below demonstrates a 4-wire resistance measurement using the 44464A breadboard assembly.



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Counter and Totalize

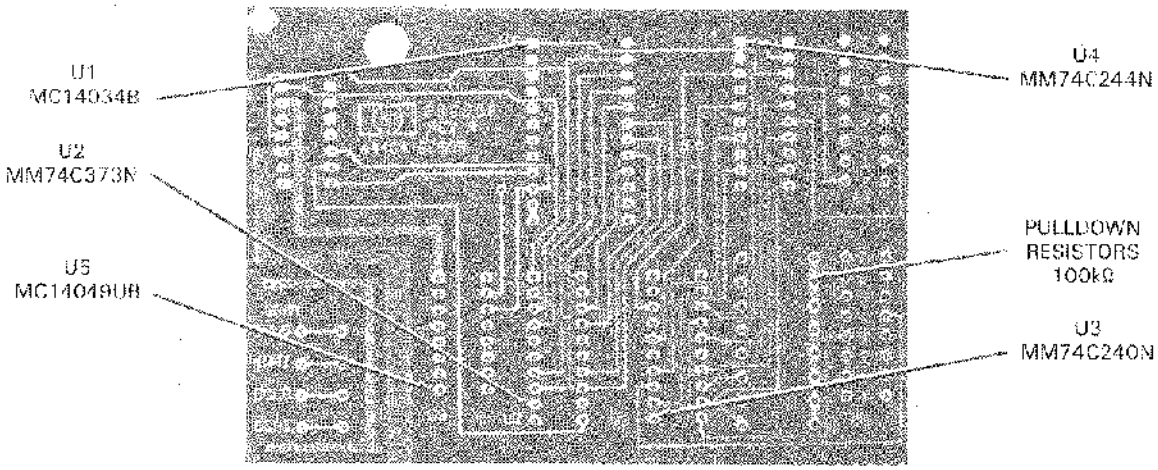
Counter and totalize measurements, like voltage and resistance measurements, are made through the DCL and DCH pins. The same constraints apply as for voltage measurements except that the FRQ command will be used for frequency measurements and TOT for totalizing.

Communication with the Mainframe

Each 44464A Breadboard assembly is designed to provide communication with the 3421A mainframe. The necessary components are not supplied with this breadboard. However, if the correct parts are installed, then two ports allow control or monitoring of relays, other digital circuits, etc. The same instruction set used with the 44465A digital I/O board is used to control either individual bits or an entire 8-bit word on the input and output ports. The following discussion is divided into the input port commands and the output port commands. For additional information and examples on programming the ports, refer to chapter 6 of this manual.

Loading The Components

Earlier in this chapter we listed the components necessary for building the digital I/O ports. The following diagram shows where to mount those components. Remember to use clean handling techniques and static protection. The integrated circuits are CMOS and susceptible to electrostatic discharge.



CAUTION

Only qualified service trained personnel should install or configure the breadboard assembly. Make certain that all power is removed from the breadboard before installing components. Use clean handling techniques and anti-static precautions.

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At the end of this chapter is a short theory of operation describing the operation of the I/O ports.

Buffering the I/O Port Lines

Since the integrated circuits installed on the breadboard for the I/O ports are CMOS devices, all I/O lines should be buffered. The 8 digital output lines are capable of driving one (1) standard TTL device.

Input Port Commands

The command set used to control the input port is the same as that used with the 44465A 8 Bit Digital I/O assembly. Two Standard Commands are used most often with the input port: REDi (REad slot i) and BITx. REDi allows you to look at the entire 8-bits from the slot specified by "i". BITx, however, permits you to select individual bits to look at. In the following discussion the words "set" and "clear" will be used. Set means that a condition is true; a high or logic "1" condition, etc. Clear means just the opposite; i.e., the bit is low or a logic "0" condition.

REDi

The REDi command reads the digital input port and responds with a decimal number between 0 and 255. This decimal number corresponds to the sum of the values of the individual bits that were "set". For example, if you have a breadboard assembly in slot 1 and bits 0,2 3, 5, and 7 are "set" (all others are cleared), the value 173 would be returned. Refer to the chart below.

Bit Number	7	6	5	4	3	2	1	0
Bit value if set	128	64	32	16	8	4	2	1

Example: 128 + 0 + 32 + 0 + 8 + 4 + 0 + 1 = 173

Bit Value Chart

BITx

The BITx command allows you to read individual bits. The following table shows the addressing scheme for the input port bits for 44464A cards in each of the three slots of the 3421A. Notice that bit addresses 08, 09, 18, 19, 28, and 29 are not allowed. The value returned to the calculator will be +1.000E+0 if the bit is set and +0.000E+0 if the bit is clear.

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Bit#	Bit Address if card in Slot #		
	Slot 0	Slot 1	Slot 2
0	0	10	20
1	1	11	21
2	2	12	22
3	3	13	23
4	4	14	24
5	5	15	25
6	6	16	26
7	7	17	27

Bit Value Address Table

Look again at the example given in the bit value chart earlier. If you execute a "BIT17" (for bit 7 in slot 1) followed by an ENTER statement, the calculator will show a value of +1.000E+0. The following program shows how this can be done. If you execute a "BIT11" (bit 1 in slot 1), followed by an ENTER statement, the calculator will return with +0.000E+0 because the bit is clear.

```
10 ! Bit example
20 OUTPUT 901 ;"BIT17"
30 ENTER 901 ; A$
40 DISP A$
50 END
```

Advanced Commands

The advanced instruction set provides added capabilities for the input port. The six commands in this group are; MHia, MLia, MNia, AN[abc], and XR[abc]. Three of these; MH, ML, and MN, may be used to cause an interrupt (SRQ) to signal the controller.

MHx and MLx

The MHx (Monitor High) command monitors the bit specified by "x". Refer to the bit value address table shown earlier to determine the value of "x". When bit "x" becomes set, the EVENT OCCURRED bit in the Status Register (bit 3) likewise becomes set. An interrupt (SRQ) is generated to flag the controller. Refer to chapter 3 under the topic of SPOLL for more information on SRQ and the Status Register. When the 3421A is addressed to talk it will output a decimal number equal to the sum of the values of the bits that were set at the time of the interrupt (similar to a REDi command). The MLx (Monitor Low) performs the same way except that SRQ is generated when the specified bit becomes cleared.

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MNi

The MNi command is very unique in that it allows you to specify combinations of set and cleared bits to cause an interrupt. MNi uses the XR[abc], AN[abc] commands to extract only the bits you want to look at. XR[abc] sets up what is called an Exclusive Or mask. It allows you to specify which bits are to be set to cause the interrupt. The AND mask is set up by the AN[abc] command and allows you to specify which bits you want to monitor. In the discussion to follow, it will help to remember these two points:

1. The AN command determines which bits you want to look at.
2. The XR command determines which bits are to be set to cause the interrupt.

The MNi command reads the input bits from the card in slot i, performs a logical Exclusive-OR with the XOR mask, takes the result and performs a logical AND with the AND mask. If the final result equals 0, the EVENT OCCURRED bit in the Status Register (bit 3) will be set. If the Status Register bit 3 is not masked, an SRQ interrupt will be generated.

The XR[abc] command sets the logical Exclusive-OR mask for the MN command. The value [abc] represents a decimal number from 0 to 255. Refer to the bit value chart shown earlier in this chapter. The Exclusive Or function performed by the MN command is done on a bit-by-bit basis. The following Truth Table and example show how the XR mask works.

Logical XOR Truth Table

Input Bit	Mask Bit	XOR Result	Example
0	0	0	1 0 1 0 1 1 0 0 - XR mask
0	1	1	0 1 1 1 0 0 1 0 - Input Bits
1	0	1	- - - - - - - -
1	1	0	1 1 0 1 1 1 1 0 - Logical XOR Result

In the [abc] value, if a or ab are not received, leading zeros are inserted. In other words, XR5 is the same as XR005. If no number is received, the mask is set to all 0's.

The AN[abc] command sets the AND mask. The value [abc] represents a decimal number between 0 and 255. Refer to the bit value chart given earlier in this chapter. The AND performed by the MN command is done on a bit by bit basis. For example, if you send AN173 this would represent a binary AND mask of 10101101

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(bit7 bit0). Suppose the digital inputs were 10011000. The logical AND would be 10001000. This is shown in the following illustration

Logical AND Truth Table

Input Bit	Mask Bit	AND Result	Example
0	0	0	1 0 1 0 1 1 0 1 - AN mask
0	1	0	1 0 0 1 1 0 0 0 Input Bits
1	0	0	- - - - - - - -
1	1	1	1 0 0 0 1 0 0 0 - Logical AND

As with the XR command, if a or ab are not received, leading zeros are inserted. In other words, AN5 is the same as AN005. If no number is received, the mask is set to all 0's.

Output Port Commands

The three STANDARD commands most commonly used with the output port are CLSx, OPNx, and WRTi,[abc]. The first two, CLSx and OPNx, allow control of individual bits in the port. WRTi, on the other hand, permits one command to control all 8 bits. In the discussion to follow, the word "set" means that the bit is high and "clear" means the bit is low.

CLS

The command CLSx (CLose Single bit x) "sets" the bit specified by x. OPNx performs just the opposite task, it clears the bit specified by x. The table below shows the bit address chart for the three different slots.

	Bit Address if card in slot#		
Bit#	Slot 0	Slot 1	Slot 2
0	0	10	20
1	1	11	21
2	2	12	22
3	3	13	23
4	4	14	24
5	5	15	25
6	6	16	26
7	7	17	27

If, for example, you have a digital I/O card in slot 1 and you wanted to set bit 5 you would execute CLS15. If you wanted to clear bit 3, execute OPN13.

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WRT

To control all bits with one command use the WRTi[abc] command. The i represents the slot number for the digital I/O card. The value [abc] is a decimal number equal to the sum of the values of the bits that you want set. See the bit value chart below. If you wanted to set only bits 3, 4, and 5 and all other bits cleared in slot 1, regardless of their previous condition, execute the command WRT1,56. This example is shown below.

Switch Number	7	6	5	4	3	2	1	0
Switch Value If Closed	128	64	32	16	8	4	2	1

Example: 0 + 0 + 32 + 16 + 8 + 0 + 0 + 0 = 56

Advanced Commands

The advanced instruction set provides added capabilities when using the output port. The two instructions from this set are DSi,[abc], and DCi[abc].

DS

The Digital SET command, DSi,[abc], sets the output port bits on the card specified by "i" to the configuration specified by the decimal number [abc]. All bits not specified by [abc] remain unchanged. The value [abc] represents the sum of the values of the bits you wish to set. Use the bit value chart shown previously to determine the value [abc]. For example, if you want bits 1 and 5 set in slot 2 and all other bits to remain in their previous state, execute the command DS2,34.

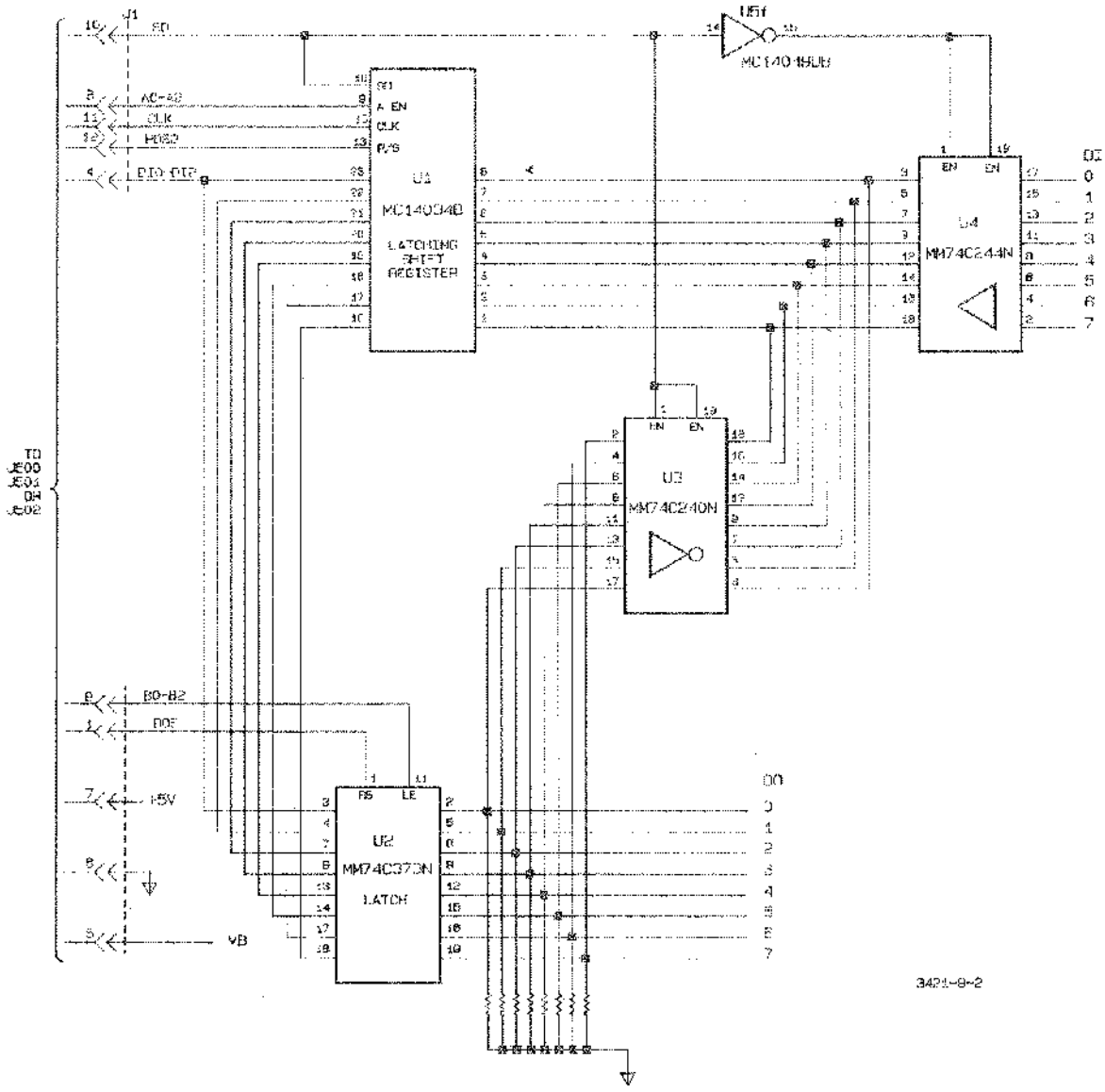
DC

The Digital Clear command DCi,[abc], clears the bits specified in the same manner as the Digital Set command set bits.

Theory of Operation

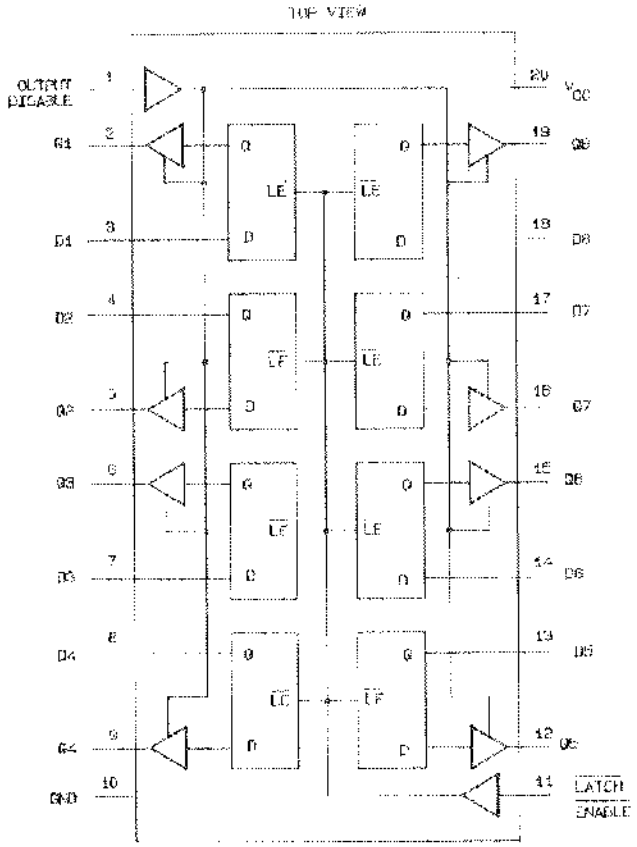
This simplified theory of operation is designed to help you understand the operation of the 8-bit input/output ports. Also, should problems occur in the input/output port, this information can assist you in troubleshooting. The following diagram illustrates the major blocks of the ports.

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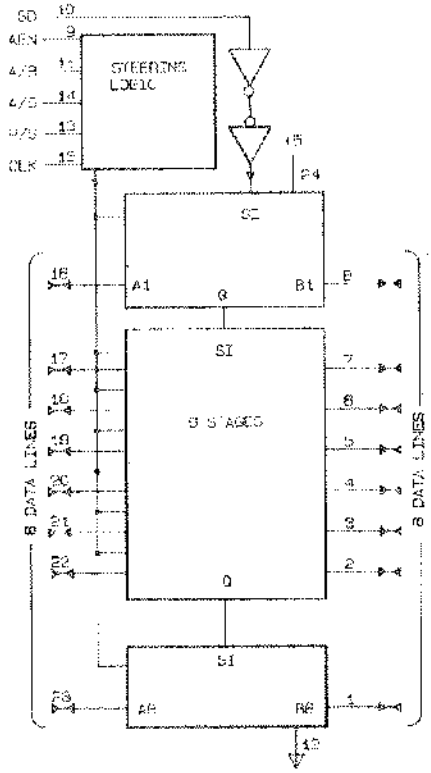


Commmunication between the 3421A internal microprocessor and the 44464A breadboard is carried on serially. U1 is an 8-bit bidirectional parallel/serial input/output bus register. This means that information from the input port, through U4, is converted to serial information by U1 and sent to the 3421A processor. Likewise, serial information from the processor is sent to U1, converted to parallel, and output through U2. U3 is provided to read back the state of the output port.

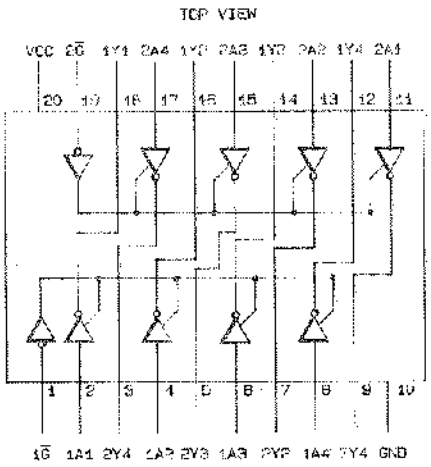
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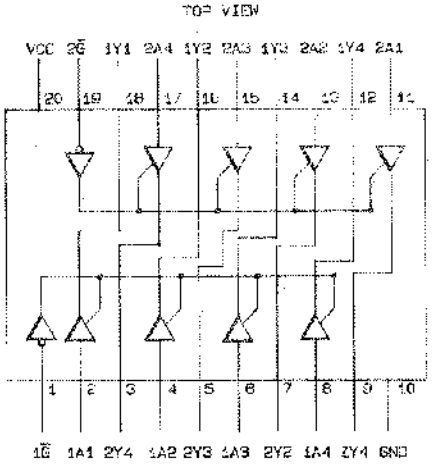
U2



U1



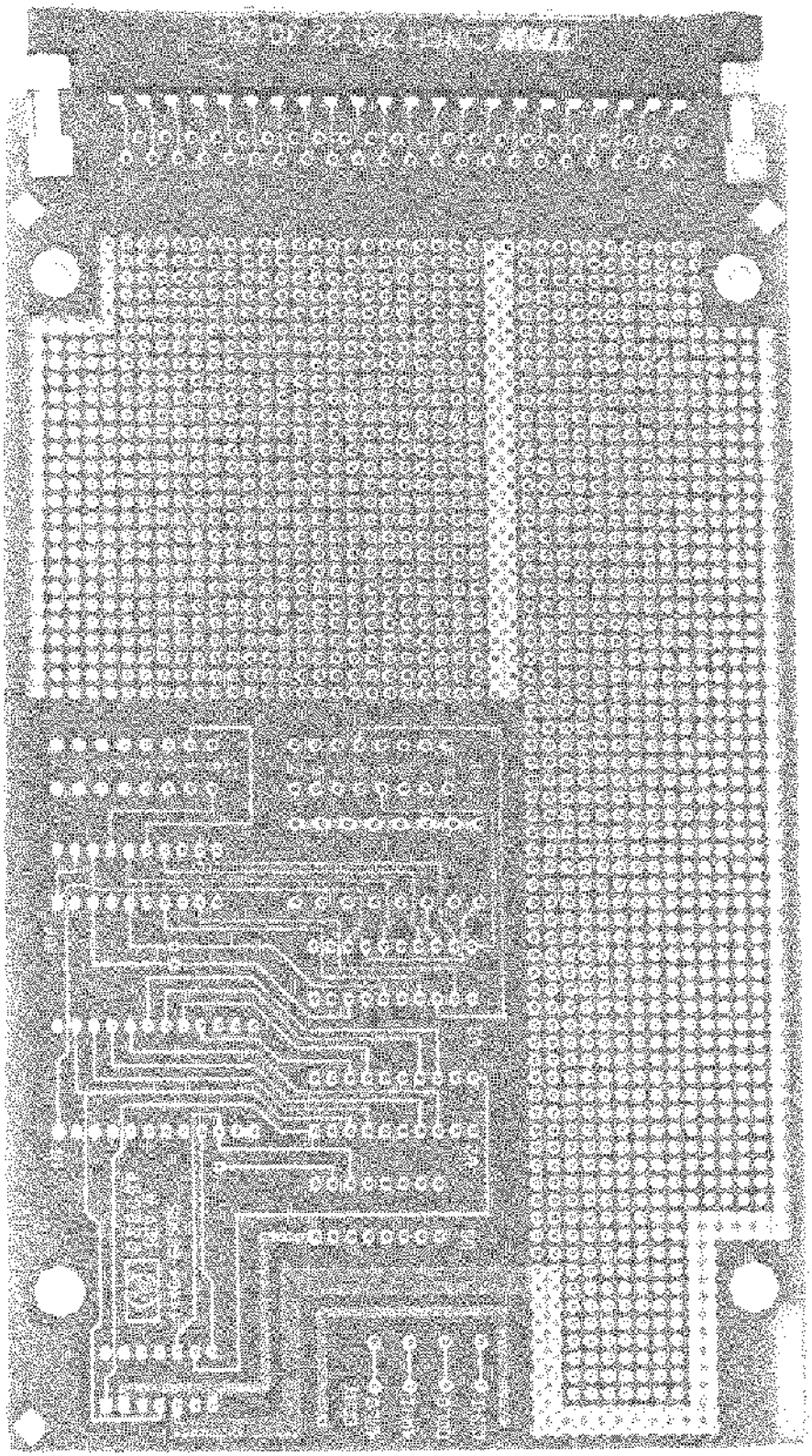
U3



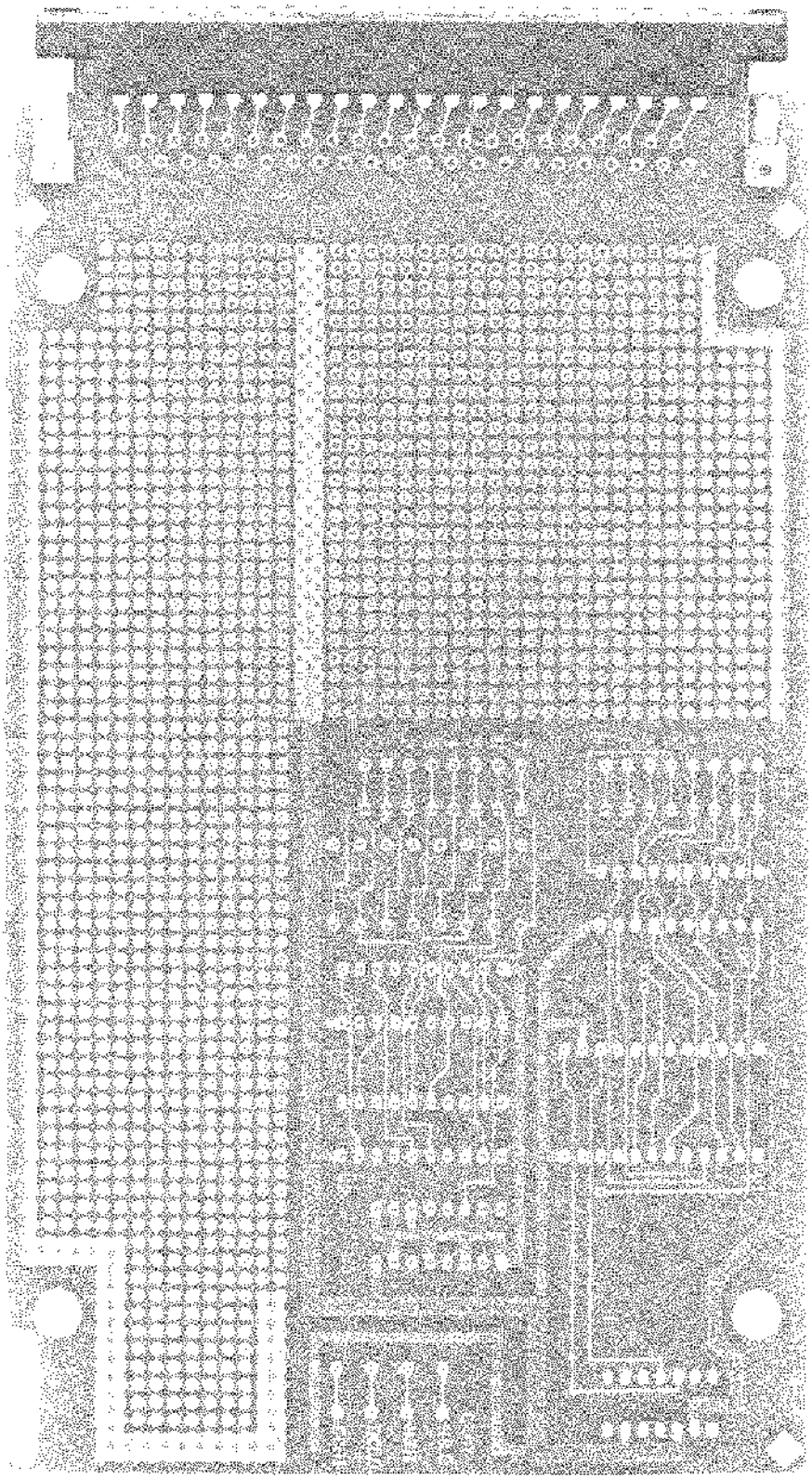
U4

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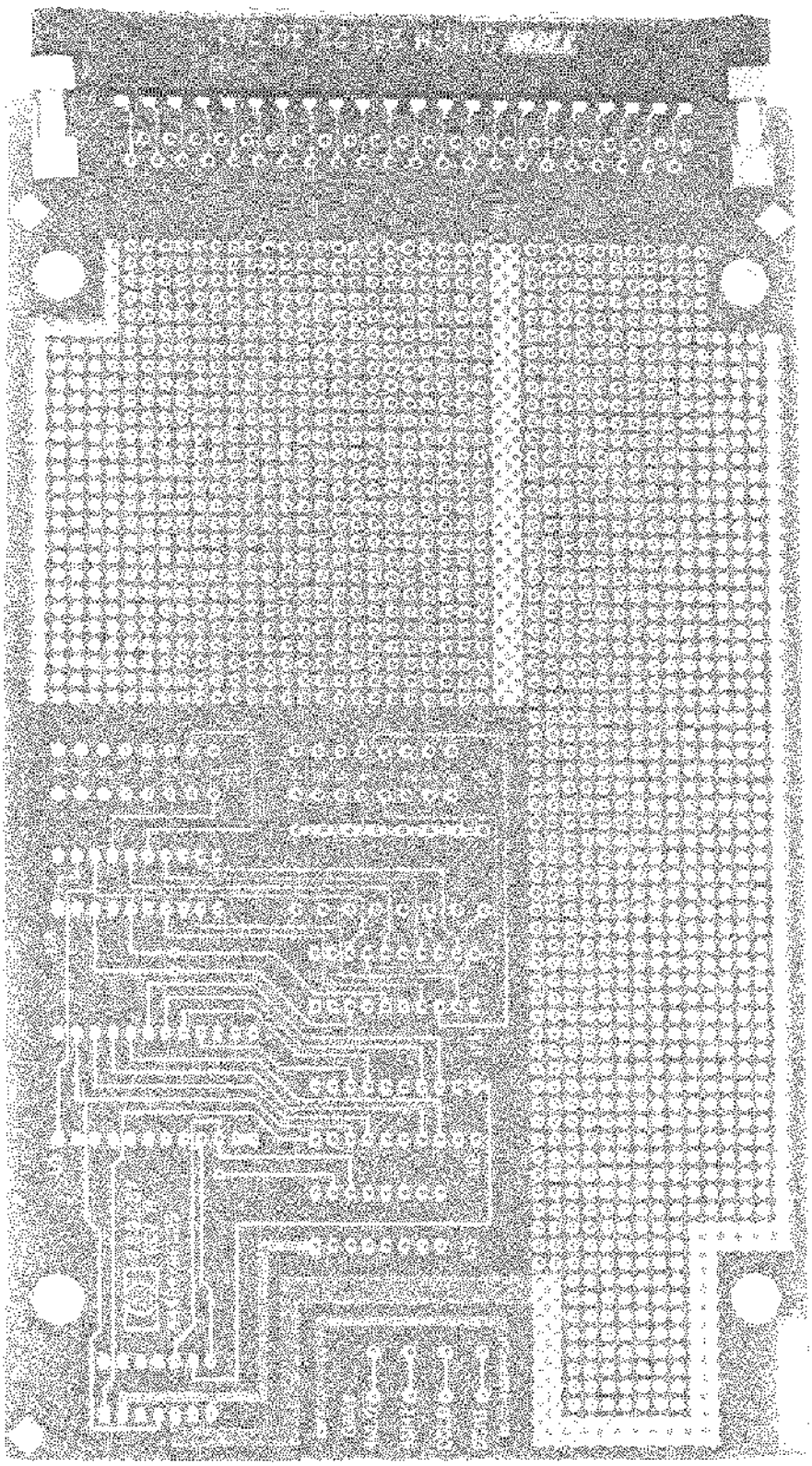
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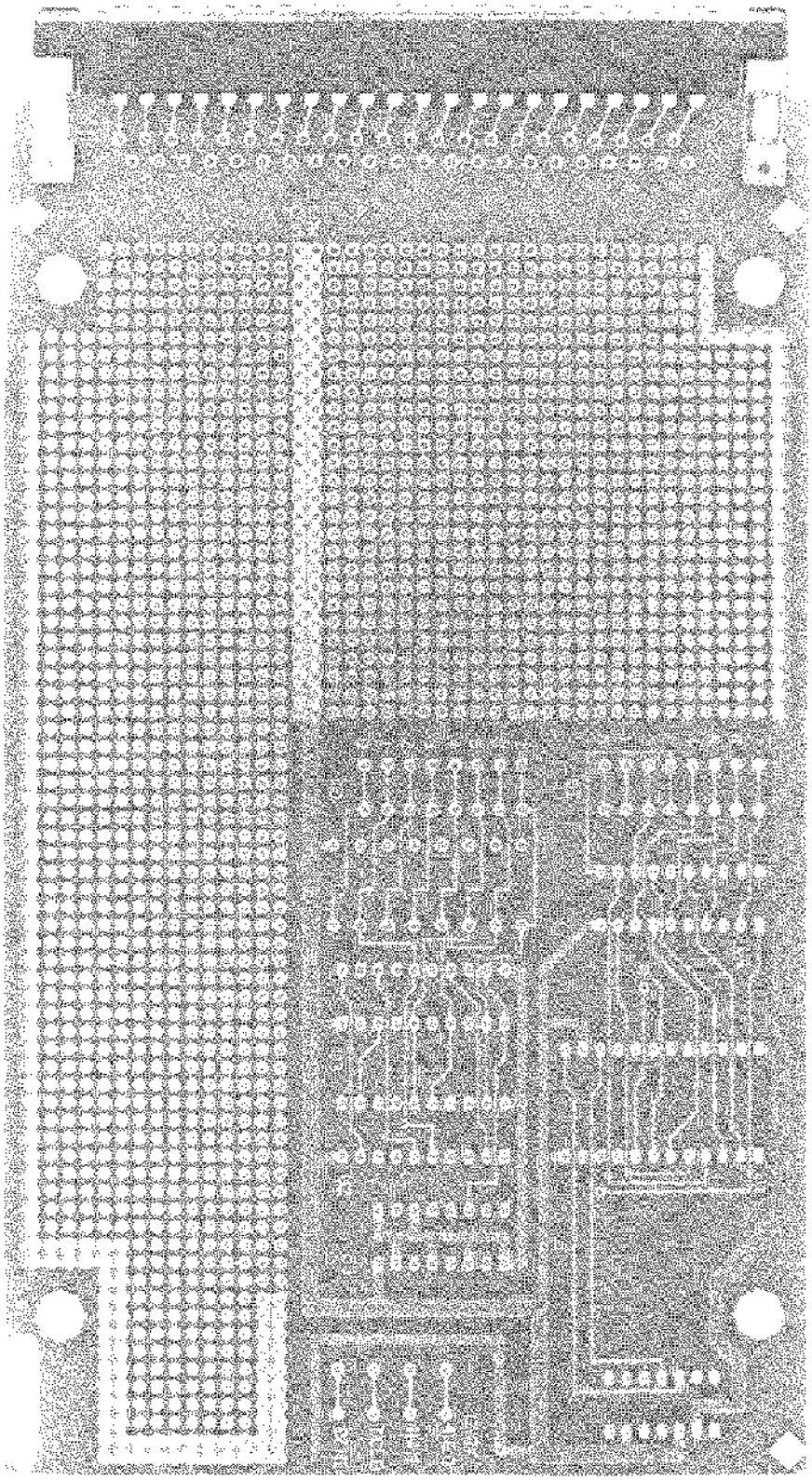
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Appendix A
Documentation Worksheet

Introduction

It has long been recognized that failure to document a measurement system, or documenting the system after its development, results in considerable extra effort. This is especially true when attempting to diagnose system failures. It can be very frustrating, for example, to suspect a defective thermocouple, and because of inadequate documentation, replace the wrong one. This is not only time consuming but costly. This appendix presents a simple method of documenting your measurement system to help alleviate these problems and to help in the setup procedure. Only two worksheets are provided, therefore you may want to tear one out and duplicate it for future use.

Worksheets

The Documentation Worksheets presented here were designed to be filled out while you are wiring transducers to the 3421A. Later, they can be used as a guide when writing programs and testing. Instructions for completing the worksheets are found on the backside of the worksheets.

These worksheets serve only as a guide for your system. That is, they may not be applicable to all situations and you may need to modify them for your individual needs. Figure A1 shows several examples of how worksheets may be filled out.

Date/Time: 8/11/82 System Name: THERMAL Test Area:

Slot/Card Type	Card Terminals	Channel	Type of Transducer	Function	Values Min	Values Typ	Values Max	Comments Location, Action
Slot 0 Relay	3	3	T-type Thermocouple	°C		23.2 °C		Grid Location: A-5
"	4	4	"	"		25.6 °C		" " A-6
"	5	5	"	"		25.9 °C		" " A-2
"	6	6	"	"		24.3 °C		" " A-3
"	8	8	2252 Ω Thermistor	4-wire Resistance		339 Ω		≈ 24.4 °C Compare against Resistance on thermistors
Slot 1 Relay	2	12		AC Line Voltage		122 VAC		Initially Measured Value by M. This figure was not in spec
"	3	13	—	"	13.0 VDC	13.29 VDC	15.0 VDC	Alarm bounds if min or max limits exceeded
"	4	14		"	3.35 VDC	3.48 VDC	3.60 VDC	Alarm bounds if min or max limits exceeded
Slot 2 Relay	9	10	(Actuator) Alarm					Normally Energized (Closed if limits
"	1	11	"					Normally Closed (Open if limits
Slot 3 Digital		20	Switch					Robot arm position switch, "Extension Position"
"		21	Switch					To Gate Circuit

Figure A-1. Worksheet Example

Page 9a.

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Event Log

In addition to the Documentation Worksheets, you may want to maintain an Event Log. Types of Event Log entries include changes in the setup, when and why the changes were made, transducer failures and any circumstances surrounding their failure, and changes in a process (e.g., use of a different brand of detergent in a washer). Each entry should include at least the following four items:

1. What the event is and the extent of change.
2. Where the event took place or was observed.
3. When the occurrence happened or was noticed.
4. The fix - if the event was a failure.

An example of an Event Log entry would be:

Power failure 10:43 a.m. 10/22
Changed T22 type K thermocouple 11:05 a.m. 10/22
Oven #3 overheated to 1700°C 3:48 p.m.
T22 appears to be bad reading 4:10 p.m. 10/22

From the Event Log, apparently T22 was change to a type K thermocouple (it was a type J, see Worksheet example), but the change was not entered into the program. While most problems are not solved this easily, the Event Log can provide valuable insight into seemingly unexplained changes in a system.

Another piece of documentation you may find useful is a single page cover sheet to identify the documentation package. This cover sheet might incorporate linearization equations, transducer manufacturers and replacement part numbers, wire batch numbers, and any other pertinent information.

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Date/Time: System Name: Test Area:

Slot/Card Type	Card Terminals	Channel	Type of Transducer	Function	Values			Comments Location, Action
					Min	Typ	Max	

Page No.

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DOCUMENTATION WORKSHEET INSTRUCTIONS

DATE/TIME: The date and/or time of the original setup should be entered here. Dates and/or times of minor alterations should be made in the left hand margin next to the addition or alteration.

SYSTEM NAME: The setup name is used to identify a particular measurement system. This is especially important when more than one system is in use.

TEST AREA: This entry should be an overall description of where the system is being used or what it is measuring.

SLOT/CARD TYPE: Refer to chapters 2, 5, and 6 of this manual for a discussion of the 3421A slots. The slot number must be known and whether the slot contains an 8-bit Digital I/O card or a 10 channel multiplexer card.

CARD TERMINALS: Record the terminal block connector numbers for each transducer. Refer to chapters 5 and 6 of this manual for discussions on card terminals. As a diagnostic aid it is important to record the terminal connections.

CHANNEL: This entry is the channel number that you specify in your program. Refer to chapters 5 and 6 for more information.

TRANSDUCER TYPE: Indicate the type of transducer used on that channel. For example, J type thermocouple, pressure transducer, etc. You may also want to indicate the replacement part number for that transducer.

UNITS/LINEARIZATION: Enter the units of the measurement and any linearization equations. Examples include pressure, liquid flow rate, FT/Lbs of torque, °F=32.0+1.8°C, etc.

VALUES/LIMITS: List a typical value for that measurement and the measurement units. Some tests require that an action take place if certain limits are exceeded. The values for these limits should be entered under MAX. and MIN.

COMMENTS, ACTIONS, ETC.: This entry should include anything not already specified that might be appropriate to the measurement. Possible entries include the specific location of the transducer, actions taken if limits are exceeded, etc.

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Date/Time: System Name: Test Area:

Slot/Card Type	Card Terminals	Channel	Type of Transducer	Function	Values			Comments Location, Action
					Min	Typ	Max	

Page No.

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Appendix B
HP-IL/HP-IB

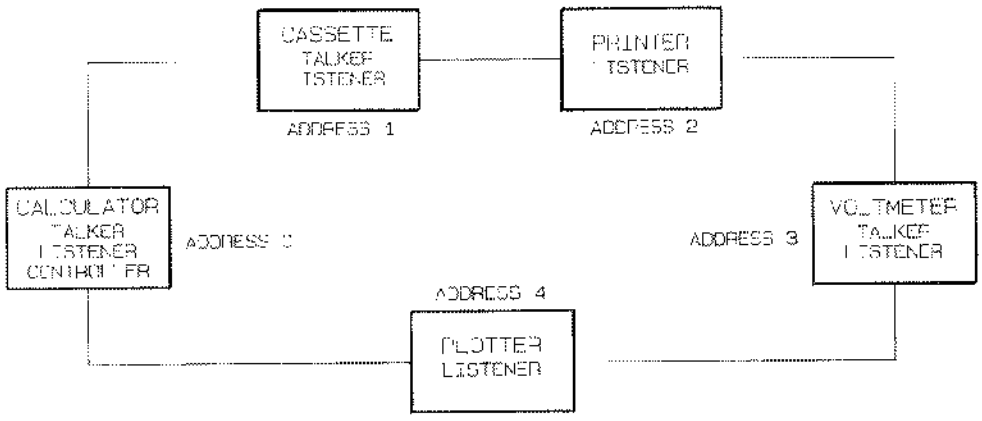
Introduction

An interface is the means by which a computer and the 3421A or other instrument communicate. This appendix provides a slightly more detailed overview of the two interfaces used with the 3421A: HP-IL and HP-IB. Although the information in this appendix is controller independent, the information may be 3421A dependent.

General HP-IL Description

Hewlett-Packard Interface Loop (HP-IL) is a two wire interface. As the name implies, devices are connected in a serial loop structure. Data or information, in the form of digital 'frames', travels from one device to the next around the loop.

The interface loop consists of a calculator/computer and up to 29 peripheral devices such as the 3421A. Information is transferred from one device to the next around the loop in one direction. If the information is not intended for a particular device (see paragraph on addressing), the device merely passes the information on to the next device. When the information reaches the intended device, that device responds as directed by the information. The information is then sent on to the next device. In this way, the calculator/computer can send information to and receive information from selected devices in the loop according to the device's capabilities. The following figure shows a typical interface loop system.



Functional Overview

Each device in the loop will possess one or more of the three basic device capabilities: Controller, Talker, or Listener. The controller, as the name implies, has

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the responsibility to control loop activity. The -hp- Model 41C/CV handheld calculator and the -hp- Model 85 desktop computer are examples of devices which serve as controllers. They must, of course, be equipped with the proper interface module. Controllers transmit all commands to other devices in the loop and have Talker and Listener capabilities. The 3421A cannot serve as a controller. Only one device in the loop may serve as a controller.

Talkers are devices that have the ability to send data or information (but not commands) through the loop. Note that a talker will not actually send data or information until told to do so by the controller. The 3421A has Talker capabilities. The 3421A does not have a Talk-only mode as do some instruments.

Listeners are devices with the capability to receive information through the loop. Listeners must remain inactive until told to listen by the controller. The 3421A has Listener capabilities.

Addressing

Each device in the loop is assigned a unique address by the controller. For example, if the 3421A is the only device in the loop, other than the controller, the controller will assign it an address of "1". The address of the controller is always "0". Addresses permit the controller to specify or "select" a particular device in the loop when sending commands. Addresses are assigned to devices sequentially around the loop in the direction of information flow. The first device in the loop after the controller is assigned an address of "1". The second device is assigned an address of "2", and so on around the loop.

Look at the figure of the typical HP-IL system again. Individual devices are shown with their basic capabilities, loop addresses, and direction of information flow.

Technical Overview

Fundamentally, HP-IL is a bit-serial, byte-serial, unidirectional interface. It uses a two wire balanced differential drive system and three level encoding for bits. Messages are sent through the loop as a sequence of eleven bits called a message frame. Commands, such as Listen, are made up of one or more message frames. There are three major classifications of frames: Command, Ready, and Data. Three of the eleven bits are used to specify the type of frame. The remaining eight bits are data bits and specify the particular message within the classification.

HP-IL protocol provides excellent error detection. Commands and data make a complete circuit of the loop. In other words, the originating device must receive the information back after all other devices have received and re-transmitted it. By comparing returning information with what was sent out, errors are automatically detected.

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Normally, only one message is in transit around the loop at any given time. In general, when a device sends a message it waits until the message is returned before transmitting the next message. This part of the process is called loop handshaking and guarantees that Talkers and Controllers do not send information faster than other devices can accept them.

HP-IL has a theoretical maximum transmission speed of 20,000 bytes per second. In a typical implementation though, this rate is lowered to somewhere between 3,000 and 5,000 bytes per second. This speed is sufficient to transmit more than a full single-spaced typewritten page of data every second.

3421A Loop Capabilities

The following table lists the HP-IL functions that the 3421A responds to and uses.

R	The 3421A handshakes as a receiver.
D	Handshakes as a driver to the next device.
AH	Handshakes as an acceptor.
SH1	Handshakes as a source.
T1,2, 3,4,6	Basic Talker, send Status, send Device ID, send Accessory ID, Unaddressed as a talker when addressed as Listener.
TE0	No extended Talker capability.
L1,3	Basic Listener, Unaddressed to listen when addressed to talk
LE0	No extended listener.
C0	The 3421A cannot serve as a controller.
AA1	Can be autoaddressed by the controller.
AE0	No auto-extended addressing capability.
AM0	No multiple addressing capability.
DC2	The 3421A responds to Device Clear and Selected Device Clear interface commands.
DT1	The 3421A responds to a Device Trigger interface command.
RL0	Remote, Local, and Local Lockout are ignored since the 3421A can only be controlled by a controller.
SR2	Basic Service Request and Asynchronous Service Request capability.
PP0	The 3421A does not respond to parallel poll.
PD1	The 3421A has a power-down mode.
DD0	The 3421A does not implement device dependent Talker or Listener commands.
MS0	The 3421A does not have manual service request capability.

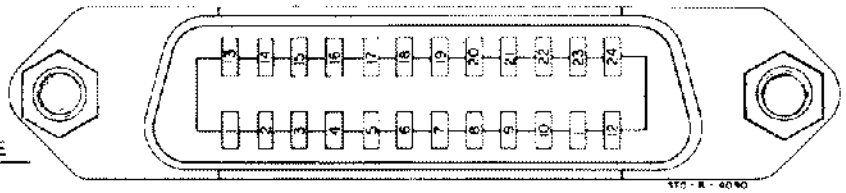
General HP-IB Description

The Hewlett-Packard Interface Bus (HP-IB) is Hewlett-Packard's implementation of IEEE Standard 488-1978, "Standard Digital Interface for Programmable Instrumentation."

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It is a carefully defined interface which simplifies the integration of various instruments and computers into systems. The interface provides for messages in digital form to be transferred between two or more HP-IB compatible devices.

The HP-IB is a parallel bus of 16 active signal lines grouped into three sets, according to function, to interconnect up to 15 devices. A pictorial view of the HP-IB connector and its pin designations are shown in the following illustration. Also shown is a diagram of the interface connections and Bus structure.

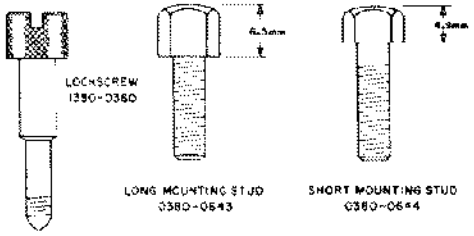


PIN	LINE
1	DI01
2	DI02
3	DI03
4	DI04
13	DI05
14	DI06
15	DI07
16	DI08
5	EOI
17	REN
6	DAV
7	NRFD
8	NDAC
9	IFC
10	SRQ
11	ATN
12	SHIELD—CHASSIS GROUND
18	P/O TWISTED PAIR WITH PIN 6
19	P/O TWISTED PAIR WITH PIN 7
20	P/O TWISTED PAIR WITH PIN 8
21	P/O TWISTED PAIR WITH PIN 9
22	P/O TWISTED PAIR WITH PIN 10
23	P/O TWISTED PAIR WITH PIN 11
24	ISOLATED DIGITAL GROUND

THESE PINS ARE INTERNALLY GROUNDED

CAUTION

The 3421A contains metric threaded HP-IB cable mounting studs as opposed to English threads. Metric threaded hp- 10631A, B, or C HP-IB cable lockscrews must be used to secure the cable to the instrument. Identification of the two types of mounting studs and lockscrews is made by their color. English threaded fasteners are colored silver and metric threaded fasteners are colored black. DO NOT mate silver and black fasteners to each other or the threads of either or both will be destroyed. Metric threaded HP-IB cable hardware illustrations and part numbers follow.

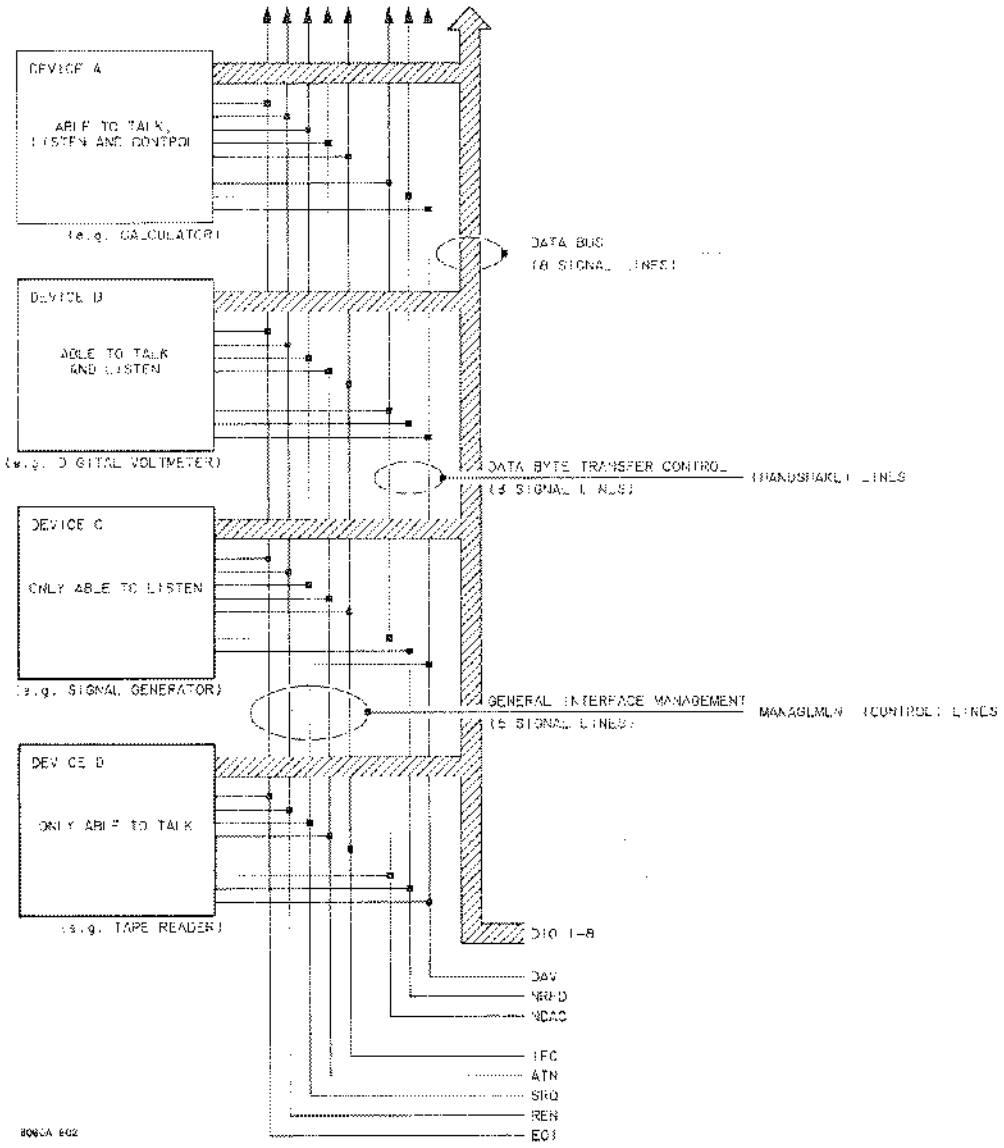


Eight signal lines, termed DATA lines, are in the first set. The Data lines are used to transmit data in the form of coded messages. These messages are used to program the instrument function, transfer measurement data, coordinate instrument operation and read its measurement data. Input and Output of messages, in bit parallel - byte serial form, are also transferred in the data lines. A 7-bit ASCII code normally represents each piece of data.

Data is transferred by means of an interlocking "handshake" technique which permits data transfer (asynchronously) at the rate of the slowest active device used in that transfer. The three DATA BYTE CONTROL lines coordinate the handshaking and form the second set of lines.

The remaining five GENERAL INTERFACE MANAGEMENT lines are used to manage the devices on the HP-IB. This includes activating all connected devices at once, clearing the interface, and others. For a detailed description of the HP-IB lines, commands, in-

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ternal operations, etc., refer to the HP-IB Abbreviated Description Manual, -hp- part number 5955-2903. A condensed description is also available in the Condensed Description of the Hewlett-Packard Interface Bus Manual, -hp- part number 59401-90090. The manuals are available through your local -hp- Sales and Service Office.

As with HP-IL, devices can be classified as either Controllers, Talkers, or Listeners. These are defined as follows.

a. Controllers: The device that can specify which device(s) on the Bus is a Talker or Listener. There can be two types of controllers; an Active Controller and a System Controller. The Active Controller is the current controlling device. The System Controller can, however, take control of the Bus even if it is not the Active Controller. There can only be one Active controller at any given time, even if several controllers are on the Bus.

b. Talkers: A talker is any device that is able to send information over the Bus when

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it has been addressed. Only one Talker may be active at a time; usually the one that is currently addressed to send data. All HP-IB computers, most HP-IB instruments and of course the 3421A, are Talkers.

c. Listeners: Devices which receive information over the Bus, when they have been addressed to listen are called Listeners. A device may or may not be both a Talker and a Listener. The 3421A has Listener capabilities.

3421A Bus Capabilities

The 3421A interfaces to the HP-IB as defined by the IEEE Standard 488-1978. The interface function subset which the 3421A implements is specified in the table below.

SH1	Source handshake capabilities.
AH1	Acceptor handshake capabilities.
T6	Basic Talker, with Serial Poll, no Talk only mode, and unaddressed to Talk when receives its Listen address.
TE0	No extended Talker.
LE0	No extended Listener.
L4	Basic Listener, unaddressed to listen when receives its Talk address.
SR1	Complete Service Request capability.
RL0	Remote Only capability.
PP0	No Parallel Poll capability.
DC1	Complete Device Clear capability.
DT1	Complete Device Trigger capability.
C0	No Controller capability.

Interface Terms

The following is used to define many of the terms and concepts used to describe HP-IL and HP-IB systems operations.

- Address. Each device connected to the interface has a unique address assigned to it. With HP-IL, the address is assigned by the controller. In HP-IB, the address is set by switches in the instrument. The address is used to specify which device connected to the interface will receive (Addressed to Listen) or send (Addressed to Talk) information.
- Byte. A byte is a unit of information consisting of 8 binary digits called bits.
- Clear. The Clear message causes the listening device(s) or all the devices connected to the interface to return to their predefined device-dependent state.

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- Device. Any instrument or unit that is HP-IL (or HP-IB) compatible is called a "Device."
- Device Dependent. An action a device performs in response to information sent through the interface. The action is a characteristic of a particular instrument and will probably vary from device to device.
- Polling. Polling is process typically used by a controller to locate a device that has requested service from the controller. There are two types of polling: Serial Poll and Parallel Poll.

  1. Serial Poll. When the controller executes a serial poll, the addressed device sends one byte of operational information called a Status Byte. If more than one device connected to the interface is capable of requesting service, each device must be serial polled until the device that requested service is located.

  2. Parallel Poll. This method obtains a Status Bit from 8 devices connected to the interface. The 3421A does not respond to a Parallel Poll.

- Require Service. A device can send this message at any time to signify that it needs some type of interaction with the controller. Of course the device must be pre-programmed to send the Service Request and the controller must be pre-programmed to respond.

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