## Errata

**Title & Document Type:** **3421A Data Acquisition / Control Unit User Manual**

**Manual Part Number:** **03421-90010**

**Revision Date:** **January 1982**

### About this Manual

We've added this manual to the Agilent website in an effort to help you support your product. This manual provides the best information we could find. It may be incomplete or contain dated information, and the scan quality may not be ideal. If we find a better copy in the future, we will add it to the Agilent website.

### HP References in this Manual

This manual may contain references to HP or Hewlett-Packard. Please note that Hewlett-Packard's former test and measurement, life sciences, and chemical analysis businesses are now part of Agilent Technologies. The HP XXXX referred to in this document is now the Agilent XXXX. For example, model number HP8648A is now model number Agilent 8648A. We have made no changes to this manual copy.

### Support for Your Product

Agilent no longer sells or supports this product. You will find any other available product information on the Agilent Test & Measurement website:

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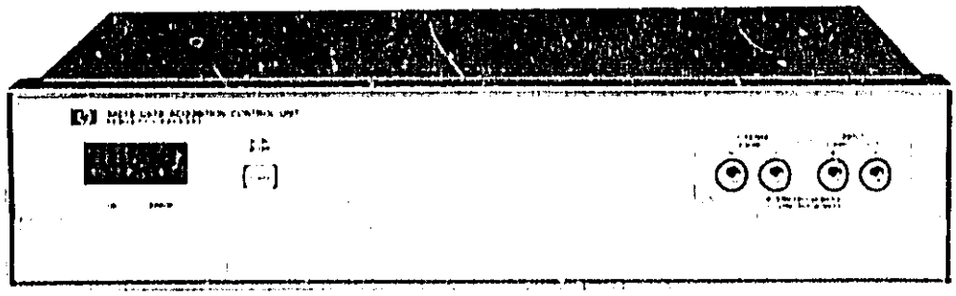
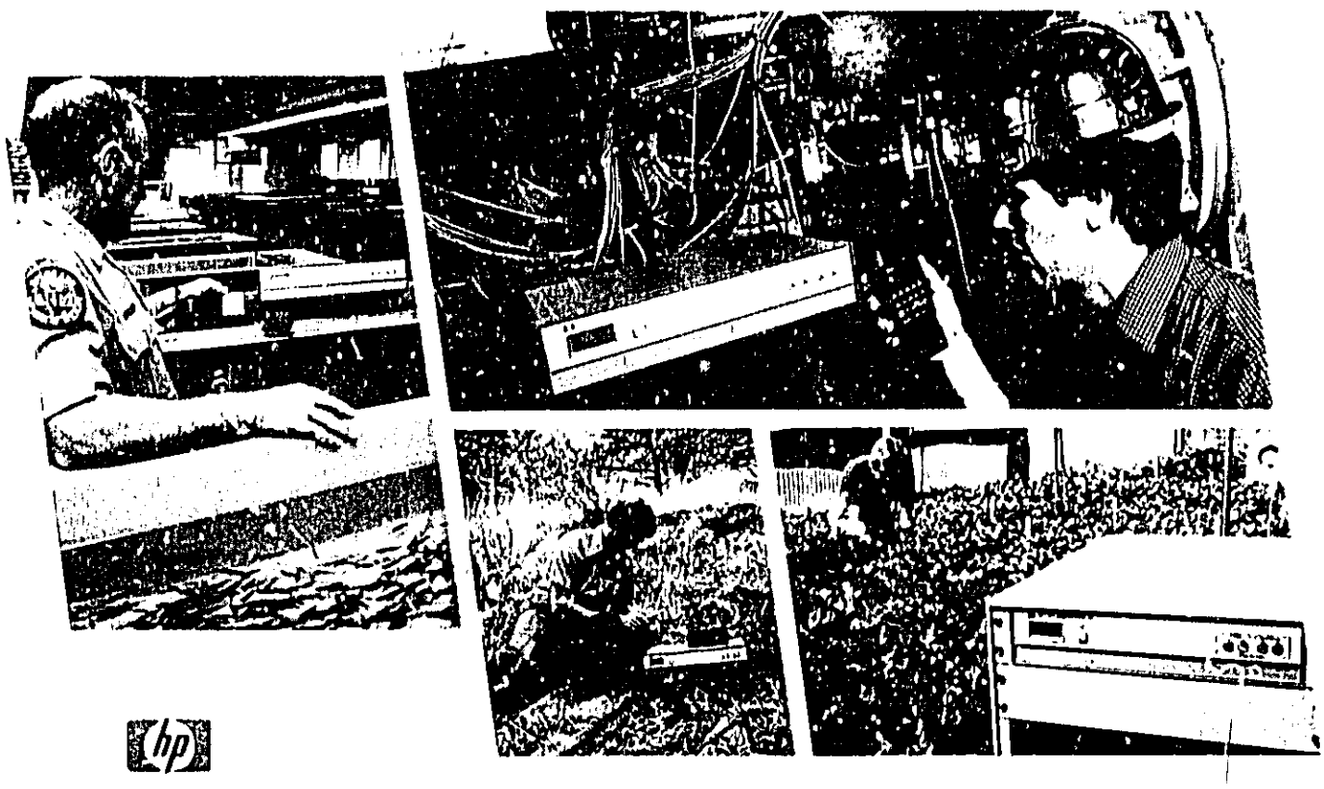
Search for the model number of this product, and the resulting product page will guide you to any available information. Our service centers may be able to perform calibration if no repair parts are needed, but no other support from Agilent is available.

Agilent Technologies

# 3421A
# Data Acquisition/ Control Unit



# Operating, Programming, and Configuration Manual



HEWLETT PACKARD

# OPERATING, PROGRAMMING AND CONFIGURATION MANUAL

# MODEL 3421A DATA ACQUISITION/CONTROL UNIT

**IMPORTANT NOTICE**

Most hp service offices in the United States are NOT authorized to service and repair 3421A DATA Unit. Notify your local hp sales office for specific information on where to send the instrument for repair.

Any changes made to instruments manufactured after this printing will be found in a "Manual Changes" supplement supplied with this manual. Be sure to examine this supplement, if one exists for this manual, for any changes which apply to your instrument and record these changes in the manual.

**WARNING**

*The 3421A uses latching relays on the multiplexer assembly (option 020, 021 or 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 insuring 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.*

**Manual Part No. 03421-90010**

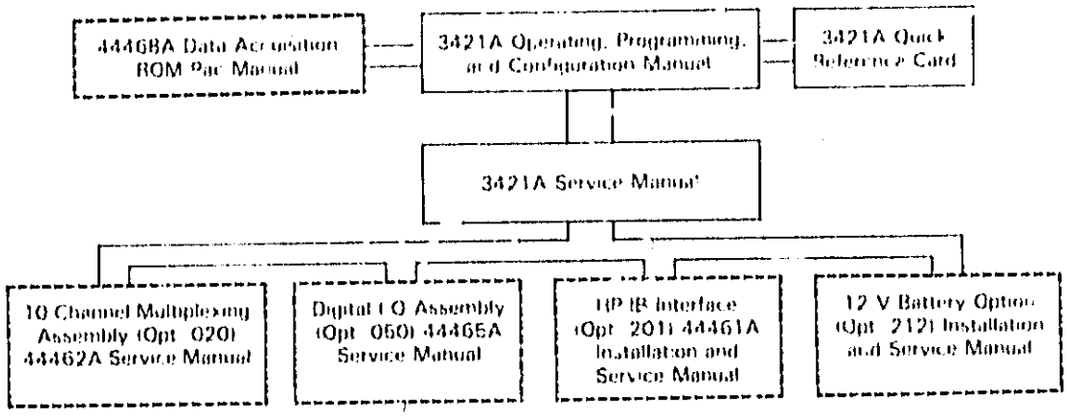
**Microfiche Part No. 03421-90060**



**Printed: March 1984**

# 3421A Manual Reference

The following block diagram shows the 3421A manual documentation scheme. Dashed line borders indicate those manuals that are shipped with the order of specific options; solid borders indicate those manuals that are shipped with every instrument.




3421A Operating, Programming, and Configuration, Manual (03421-90010) for all users. All features and options of the 3421A are discussed in this manual.

3421A Quick reference Card (03421-90002) for all users. This card is a quick reference to all of the 3421A commands.

3421A Service Manual (03421-90008) for the service technician. Theory of operating, calibration, and troubleshooting are discussed.

44462A Service Manual (44462-90000) for the service technician. This manual covers installation and troubleshooting for the option assembly.

44465A Service Manual (44465-90000) for the service technician. This manual covers installation and troubleshooting for the option assembly.

44461A HP-IB Interface Installation and Service Manual (44461-90001) for the service technician. This manual covers installation and troubleshooting for the HP-IB option assembly.

12V Battery Option (Opt. 212) Installation and Service Manual (03421-90009) for the service technician. This manual explains how to connect the 12V Battery Option to an external 12V source and how to troubleshoot the option assembly.

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## TABLE OF CONTENTS (Cont'd)

## TABLE OF CONTENTS (Cont'd)

## TABLE OF CONTENTS (Cont'd)



## LIST OF ILLUSTRATIONS

# Chapter 1
# Meet The 3421A

## Introduction

Welcome to the world of high performance, low cost data acquisition and control. Your new -hp- Model 3421A is a fully programmable unit combining precision measurement capability with process monitoring and control functions. When interfaced to an -hp computer (such as the HP-85) or handheld calculator (such as the HP-41C/CV), the 3421A forms a versatile, easy to use data acquisition and control system.

The standard 3421A consists of a mainframe, a built-in 5 1/2 digit voltmeter, a 10 kHz counter, and an HP-IL controller interface. Compensated temperature conversion using T-type thermocouples is also built in. The mainframe can hold up to three option assemblies. Available options include a 10 Channel Multiplexing Assembly, an 8-bit Digital I/O Assembly, and a Breadboard Assembly for custom circuit design. In addition, an optional HP-IB* interface or a 12V Battery Option is available.

Typically, at least one Multiplexing Assembly (44462A or option 020, 021, or 022) is used in the 3421A. This assembly provides 10 channels for signal input. A temperature reference junction is built in to each assembly for thermocouple compensation. In addition, two of the channels can be configured as actuators for controlling motors, alarms, etc.

The 8-bit Digital I/O Assembly (44465A or option 050) provides an 8-bit input port and an 8-bit output port. Typical uses for this assembly include monitoring limit or position switches, and low voltage actuating. The 3421A command set provides for individual bit control as well as 8-bit word control.

If neither of these assemblies meet your needs, Option 040, the Breadboard Assembly is available. This option permits you to custom design and build your own measurement or control assembly.

All of the 3421A features are completely programmable. A powerful instruction set means that the 3421A is very easy to use in a wide variety of applications. The major features are:

* HP-IB (Hewlett-Packard Interface Bus) is Hewlett-Packard's implementation of IEEE Standard 488-1978 and ANSI MC1.1.

- HP-IL interface for connecting to the HP-41C/CV calculator or computers such as the HP-85. An optional HP-IB interface is available for interfacing to other computers.

- The 3421A may be combined with the HP-41C/CV handheld calculator, HP-82162A thermal printer/plotter, and HP-82161A digital cassette drive for a complete battery operated data acquisition system.

- Fully programmable 5½ digit voltmeter for measuring DC voltage, AC voltage, and 2- wire and 4- wire resistance measurements.

- Programmable power down, standby mode to conserve battery power in remote location usage.

- Memory storage for 30 readings allows fast data acquisition for later manipulation.

- Programmable counter for frequency measurements up to 10kHz or totalizing up to 65535 counts.

- Low thermal offset switching with built-in reference junction.

- Digital I/O for process control and monitoring.

## Introduction to Data Acquisition and Control

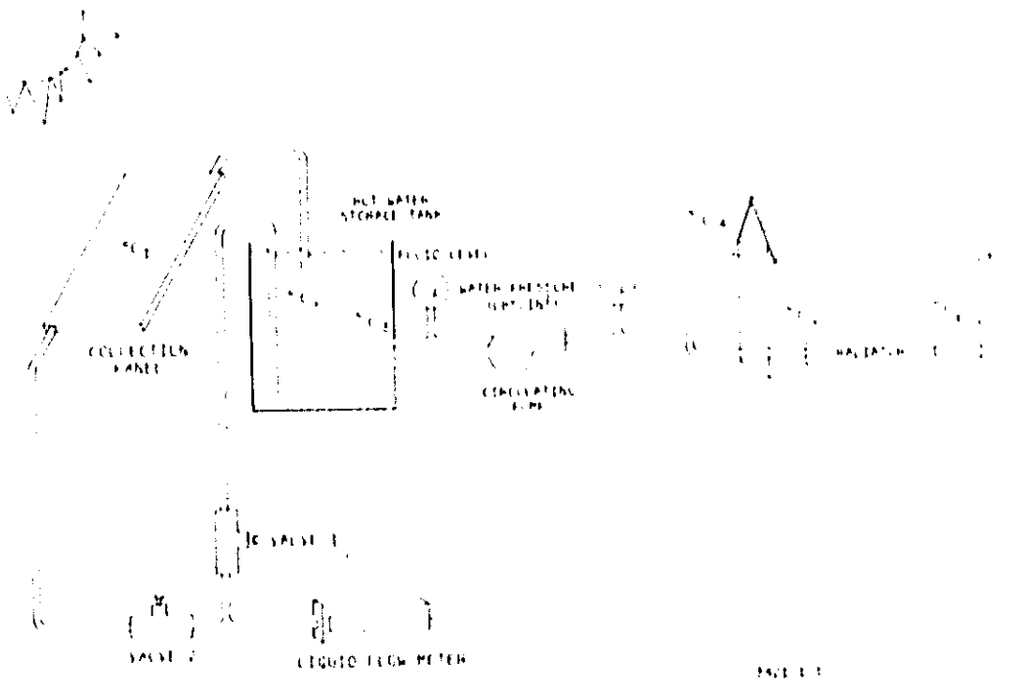
As the core of a data acquisition and control system, the 3421A is capable of being used in many application areas where data received from various transducers needs processing.

For example, in the areas of production control, quality assurance, and final test, the 3421A provides uniform and precise measurements. Using the 3421A to test and monitor prototypes can mean better knowledge of the product and therefore shorter development times in the R&D lab. Battery operation and the 3421A's light weight allow you to transport the system to out-of-the-way locations.

All of this is made possible because of the 3421A's ability to perform several measurement tasks under computer control. Tests can easily be altered to fit other applications. Instrument cost and setup time is greatly reduced since the measurement system is contained in one package.

A simple solar heating demonstration will help you to visualize where the 3421A fits into a data acquisiton/control system. This illustration shows the power and flexebility of the 3421A under computer control. In the following illustration, several parameters are to be measured including the temperature at different locations, fluid pressure on both sides of a pump, fluid flow and fluid level. Furthermore, the pump and two valves must be controlled, i.e., turned on or off.

The 3421A, under computer control, measures the various temperatures and transducer outputs and sends the data to the computer. The computer analyzes, records, and plots the data. But more than that, the computer makes certain decisions based upon the measured data and instructs the 3421A to actuate (turn on) the pump or valves. Several other functions may be included such as sounding an alarm if the pump pressure drops sharply or the liquid level in the tank is below normal.



# How To Use This Manual

This Operating, Programming, and Configuration Manual has been designed for you to serve as a complete reference document for using the 3421A. It covers both programming information and configuration/installation/connection information for the option assemblies. Information on Operator Maintenance, such as power requirements and specifications, are placed later in the manual, in Chapter 7. If you have just received your 3421A you will want to read this information. Chapters 8 and 9 discuss installing the option assemblies and the breadboard option (Opt. 040), respectively, and are intended for use only by qualified service trained personnel. A separate service manual for the 3421A contains information on calibration, performance testing and service.

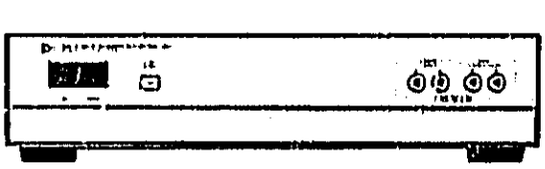
Familiarize yourself with the 3421A by looking through this manual. The best way to feel at ease with the instrument is to sit down with this manual, the 3421A, and your calculator and perform the examples shown. It won't take long to become familiar with the instrument and its many features.

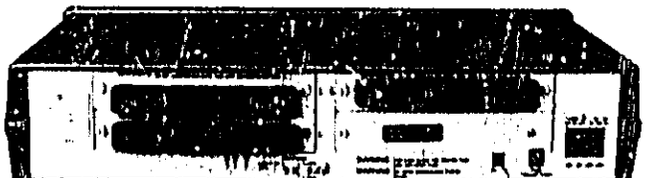
The following paragraphs will serve as a guide to direct you to the remaining chapters in this manual. Acquaint yourself with the manual by reading through these descriptions.

# Section I, Operating and Programming

## Getting Started
## Chapter 2

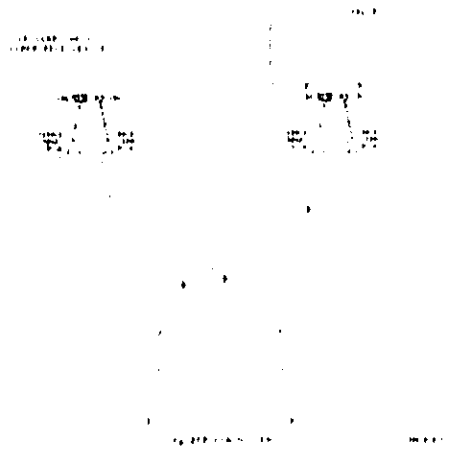
Chapter 2 discusses each function and feature of the 3421A. Major sections are devoted to the voltmeter, counter, and temperature measurements. Other topics include the power-down "sleep" mode, battery operation, and optimizing reading rates. This chapter should be read before you begin programming the 3421A as it sets a foundation for the remainder of the manual.





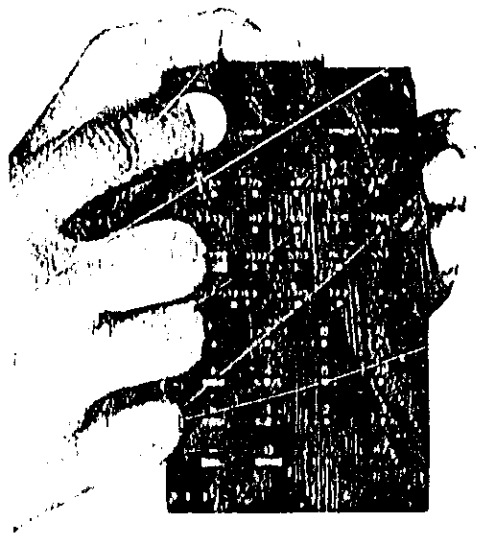
## BASIC Language Programming Chapter 3

Desktop computers with HP-IL or HP-IB capability, such as the -hp- Model 85, may be used to program the 3421A. Chapter 3 covers this subject and provides examples to enhance the discussion. Several application programs are provided throughout the chapter. Immediately following this chapter are several blue pages called a Command Directory. This directory explains each command the 3421A responds to and provides simple program examples.

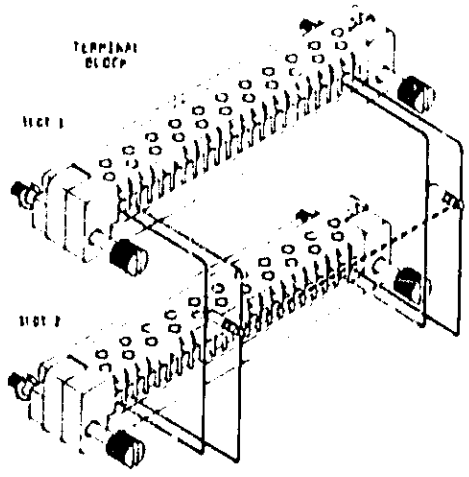


## Programming With the -hp- Model 41C/CV Calculator Chapter 4

The -hp- Model 41C family of hand-held calculators can be used to program your 3421A. This chapter teaches you how to execute simple, one-line commands from the calculator and then shows you how to write simple programs for controlling the 3421A. At the end of the chapter are several application programs. Note that the assumption is made in this chapter that you do not have the HP-44468A Data Acquisition Pac ROM for the 41C/CV (option 641 for the 3421A). If you do have the 44468A, refer to its manual.

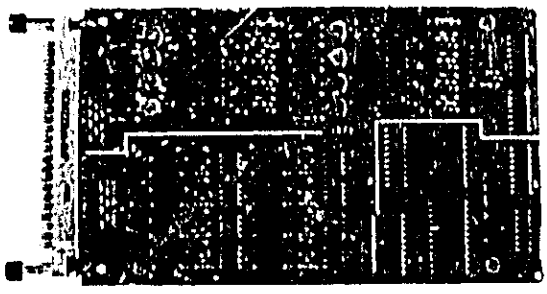


## 44462A
## 10 Channel Multiplexing Assembly
## Chapter 5



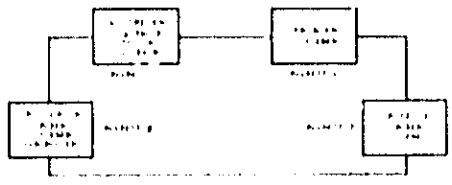
This chapter describes the features of the 44462A (opt. 020, 021, or 022) assembly and the many ways it can be used. Topics include voltage measurements, resistance measurements (both 2- and 4- wire), temperature measurements, and actuators. Several examples are provided to aid you in understanding and using the assembly.

## 44465A
## 8-Bit Digital I/O Assembly
## Chapter 6



The 8-bit Digital I/O assembly (opt. 050) can be used in a wide variety of applications where on/off, present/not present, etc. conditions occur. This chapter shows how the assembly can be used to sense position or limit switches and control relays. Examples are scattered throughout the chapter.

## Operators Maintenance
## Chapter 7



This chapter addresses 3421A installation procedures (option installation is discussed in chapter 8). It also contains a complete table of specifications, what to do if you suspect a malfunction, and many other items of special interest to the operator.

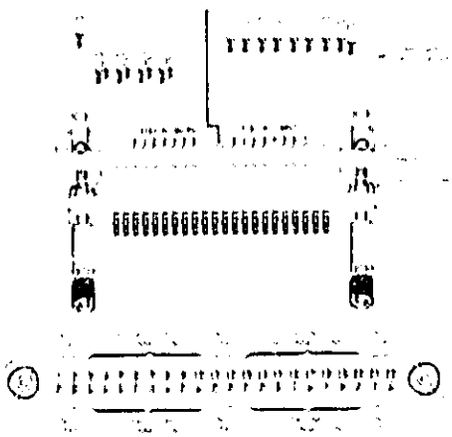
# Section II, Option Assembly Installation and Configuration

CAUTION

*Only service trained personnel with an understanding of electronic circuitry and the hazards involved should install or reconfigure the option assemblies. The two chapters described below contain installation and configuration information.*

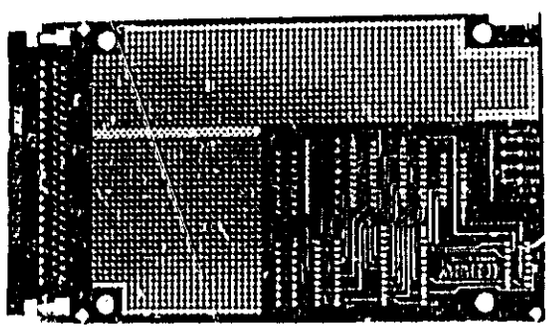
## Installation
## Chapter 8

This chapter details the installation procedures for the option assemblies. Also included are discussions of jumper configurations and connections to the device under test.



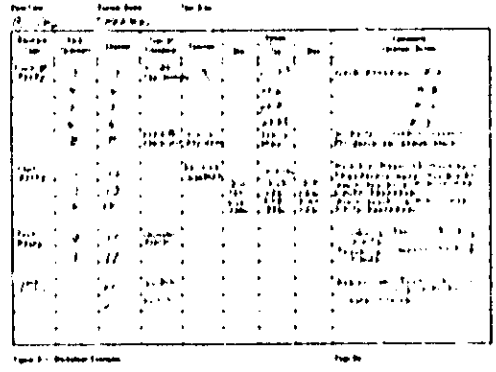
## 44464A
## Breadboard Assembly
## Chapter 9

The Breadboard option (opt. 040) is discussed in this chapter. Details are provided for using the assembly for custom designed circuits. Specifications include component height, power dissipation, and power supply requirements.



## Documentation Worksheet Appendix A

All too often it is discovered that documentation has been totally forgotten until the hardware and setup work have been done. Frequently this results in considerable effort and in documentation that does not accurately reflect the work that has been done. This appendix helps to alleviate the problem by providing a simple worksheet which can be completed simultaneously with the hardware and programming tasks.



## HP-IL/HP-IB Summary Appendix B

Appendix B provides a more detailed explanation of the two interfaces than provided in the rest of the manual. Refer to it for technical information on the HP-IL and HP-IB interfaces.


# Section I
# Operating and Programming

WARNING

*The 3421A uses latching relays on the multiplexer assembly (option 020, 021, or 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 insuring 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.*

# CHAPTER 2

# Chapter 2
# Getting Started

## Introduction

As a data acquisiton/control unit, the -hp- model 3421A is a self contained measurement system. A computer and of course your transducers are the only other devices required for data gathering and analysis. In the first chapter you saw the very basics of a data acquisition system. With this chapter you will begin learning how the features of the 3421A can solve many of your measurement needs. The information in this chapter represents a comprehensive description of the 3421A and its many features. For information on the three option assemblies, refer to Chapters 5, 6, and 9. Chapter 5 covers the 44462A 10 Channel Multiplexing Assembly and Chapter 6 covers the 44465A Digital I/O Assembly. The option 44463A Breadboard Assembly is discussed in detail in Chapter 9.

## Operating Characteristics

The main operating characteristics of the 3421A are detailed in the table below. This table is an abbreviated set of 3421A specifications. You will probably find that this table answers most of your questions about the capabilities of the 3421A without laboring over several pages of specifications. The complete Table of Specifications for the 3421A can be found in Chapter 7 of this manual.

**DC Volts:**

1μV sensitivity (.3V range) to 300V full scale
$R_{in}$: $>10^{10}$, .3 and 3 V ranges
10MΩ ± 1%, 30 and 300V ranges

**AC Volts:**

100μV sensitivity (3V range) to 30V full scale
Bandwidth: 30 Hz to 2kHz
Average responding converter

**Resistance:**

1mΩ sensitivity (300 Ω range) to 30MΩ full scale
Maximum open circuit voltage: 6.6 volts
Current through unknown resistance:

| | |
|---|---|
| 300,3kΩ ranges | – 1 mA |
| 30kΩ range | – 100μA |
| 300kΩ range | – 10μA |
| 3MΩ range | – 1μA |
| 30MΩ range | – 0.1μA |

**Counter:**

Frequency response – 1Hz to 10kHz (> 1.5mS risetime)
Sensitivity: 600mVp-p
Minimum pulse width: 50μS
Input impedance: 10MΩ +1,-10%

**Totalize:**

Maximum count = 65535
Minimum pulse width (5V) = 50μS
Minimum pulse period = 100μS

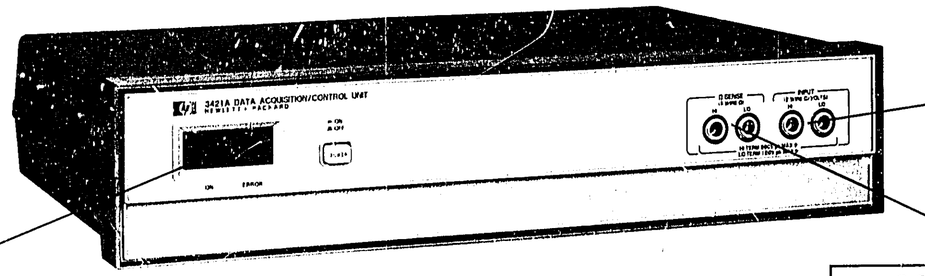
**Temperature (Type T thermocouple):**

Temperature Range = -200°C to +400°C

Internal reference junction for software compensation.

# AN OVERVIEW OF THE 3421A

## Front Panel




### Display

A 30 digit display is used on the 3421A to indicate which channels are closed. During turn on, they are also used to indicate the self test failures and the HP-IB address (if appropriate). Small "trees" are used to indicate when power is on or when an error exists.

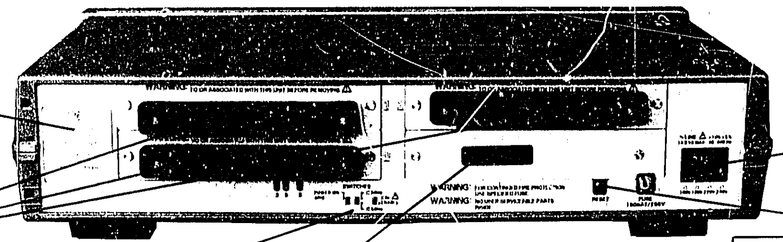
### Input

These are the voltmeter and counter input terminals.

### Ω Sense

These terminals are used for the voltmeter sense leads when making 4-wire ohms measurements.

## Rear Panel



### Model and Serial Number Plate

### AC Line Cord and Fuse

### Option Slots

There are three slots for optional assemblies in the 3421A. Strain relief is provided for transducer wires.

### Rear Panel Control Switches

### HP-IL Connector

### Reset Switch

This reset switch is provided to completely remove operating power (as long as the switch is held in) from the 3421A. This is to be used only in case of failure.

## HP-IB Option

### HP-IL Connector

### HP-IB Connector

### HP-IL/HP-IB Switch

# The 3421A In Detail

Because the goal of this chapter is to provide the most comprehensive description of the 3421A and its features, this chapter is divided into 14 major subject headings. Each subject details a particular feature or function of the 3421A. At the end of most subjects will be a short list of Standard programming commands relating to that subject. The subject headings are:

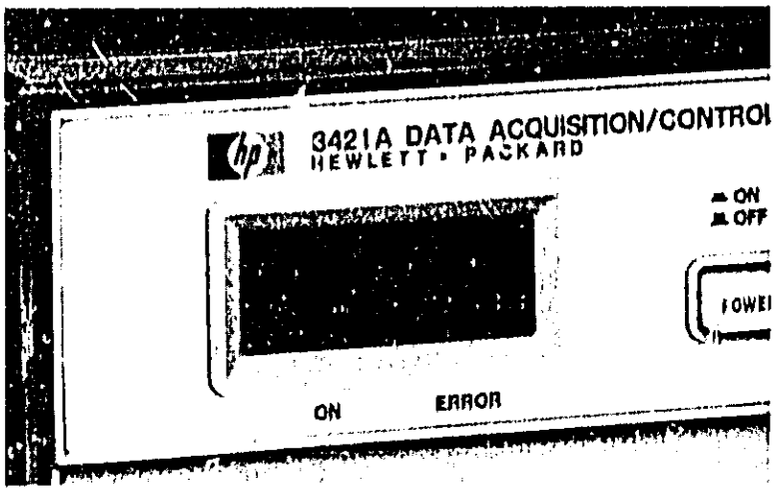
# TURN-ON

Before applying AC Power to the 3421A, check the rear panel line voltage option label to be certain the instrument is set for the nominal line voltage in your area. If necesary, refer to the installation information in Chapter 7 of this manual. As you press the POWER switch, very carefully watch the display as the 3421A goes through its turn-on sequence and self test.

## What Happens at Turn-on

At turn-on, the 3421A performs a series of 8 internal self tests. If any of them fail, the ERROR indicator is turned on in the display and the 3421A attempts to interrupt the computer (see SPOLL in chapter 3). A complete description of the self test will be given later in this chapter.

Next, you will hear a relay 'click' inside of the 3421A as all numbers in the display light up (see photo). These numbers will be on for about 1 second. Afterwards, if a failure is detected by any of the self tests, one or more numbers will light up in the display (for 1 second) indicating which test(s) failed. These numbers are assigned as follows.



# TURN-ON (Cont'd)

| Number lit | Self Test Failed |
|---|---|
| 0* | Calibration RAM checksum error |
| 1 | ROM 1 bad |
| 2 | ROM 2 bad |
| 3 | A/D Slope error |
| 4 | Microprocessor RAM bad |
| 5 | Internal RAM 1 bad |
| 6 | Internal RAM 2 bad |
| 7** | Failed 10 Mohm test (not within ± 20%) |
| 27 | Low Battery. See section on Battery Operation. |

* Error #0 will also occur if an option 44462A 10 channel multiplexer is added or moved to a different slot after the 3421A was calibrated. This is because the temperature reference was not calibrated.

** Error #7 will also occur if there is anything connected to the front panel input terminals or HCOM and LCOM on an installed 44462A 10 channel multiplexer assembly during the self test.

After the self test, you will hear the relay 'click' again. At this time, if the HP-IB add-on option is installed (option 201) and if the HP-IB/HP-IL switch is 'in' (for HP-IB), the 3421A will indicate the HP-IB address. This address will be displayed for about 1 second. After this, the 3421A will go to the following states:

- All 44462A option board(s) relays are open.
- All 44465A Digital output bits are cleared (high impedance state).
- Mainframe input relays are open.
- DC Volts function, Autorange on (starts on 300V range), Autozero on, 5 1/2 digits of resolution asserted.
- Counter set to 1 second gate time.
- Monitors rear panel switches and responds accordingly.
- The channel list (see chapters 3–6) set to all available multiplexer channels from lowest channel number to highest channel number.
- Request service from the computer if self test failed or Power-on SRQ enabled (rear panel switch).

The entire turn-on sequence takes only 2 to 3 seconds to complete.

# BATTERY OPERATION

Before operating the 3421A from its internal battery, ensure that the battery is fully charged. Connect the instrument to an appropriate AC power source and allow 16 hours for a full recharge with the POWER switch OFF (out). A fully charged battery will provide a minimum operating time of 12 hours. Operating the 3421A with the proper AC power source and the POWER switch ON (in) will provide a complete battery recharge in 21 hours. If the HP-IB option is being used, operating time is reduced to 6 hours.

## Low Battery

**CASE 1.** If the battery becomes discharged (low battery) while the 3421A is in operation, the error indicator will light and the 3421A will require service from the computer (see REQUIRE SERVICE in Chapter 3). After 3 minutes, all relays, including those on the 44462A Multiplexer Assemblies, will be opened and the 3421A will power down. This is done to prevent the battery from becoming discharged. The HP-IL wakeup (see PWRUP in Chapter 4) is disabled when low battery occurs and will not be re-enabled until the battery is charged (or AC power applied) and the 3421A front panel POWER switch is cycled on and off.

During the three minute period after low battery occurs, most 3421A commands (i.e. DCV, FRQ, etc., see the blue pages at the end of Chapter 3.) as well as interface commands (i.e. TRIGGER, CLEAR, etc.) can be executed. This includes the loop power down (see PWRDN in Chapter 4) but remember that the 3421A cannot wake up (loop power up) until the battery is recharged or AC power connected to the rear panel. The 3421A commands that cannot be executed during this three minute period are: ML, MN, TOT, and DT.

Any commands executed during this three minute period will reduce the time before the 3421A powers down.

If a CLEAR, Reset (RS), SPOLL, etc. is executed, the 3421A will cease to require service from the computer but will still power down after the three minute period.

**CASE 2.** If a low battery is detected as the 3421A is turned on, the number 27 will appear in the display. The 3421A waits 3 seconds and then powers down. It will not go through self test or respond to any commands.

NOTE

*If a low battery occurs, connect the 3421A to an AC power source and cycle the front panel LINE switch. If this is not done, the HP-IL wake-up circuitry will not work properly.*

# CALIBRATION

## What is Electronic Calibration?

One of the many features of the 3421A is electronic calibration. Although it is beyond the scope of this manual to present the entire calibration procedure, there are some points of interest the operator should be aware of. For complete calibration information, refer to the 3421A Service Manual.

Briefly, electronic calibration is performed by applying a known stimulus (voltage, resistance, etc.) to the 3421A. The 3421A is then told the exact value of that stimulus. Ten readings are taken by the 3421A and the average is compared to the exact value sent to the 3421A. A "CALIBRATION CONSTANT" is calculated to correct the averaged value to the known value. This Calibration constant is stored in the 3421A's calibration memory. Calibration constants are generated for each measurement function and range of the instrument. All subsequent measurements are corrected by the calibration constants. The calibration constant memory is backed-up by a long life battery to maintain the constants even when power is turned off.

## Temperature Calibration

If you are using thermocouples with the 3421A to measure temperature, each 44462A Multiplexing Assembly must have its reference junction calibrated. Refer to the 3421A Service Manual. Ideally, temperature calibration should be done with the 3421A in the same physical position as it will be used. This is to eliminate any thermal gradients inside the case. Furthermore, 44462A assemblies must not be moved around inside the case, or plugged into a different slot, after calibration has been performed. If you send the 3421A to an -hp- service center for calibration, leave all option assembiles installed in the instrument case.

## Calibration Enable

On the rear panel of the 3421A is a bank of eight small switches. Three of the eight switches are accessible without opening the 3421A case. Switch number 8, the rightmost switch, is the CALibration Enable switch and when set to the down position enables the 3421A to be calibrated. This switch should not be set (down position) except when qualified service trained personnel are to perform the calibration procedures. Enabling the CAL switch may result in loss of calibration if proper procedures are not followed.

### 3421A COMMANDS

Cx—Calibrate to value "x"
(see the 3421A and Service Manual)

# CHANNELS

## What is a Channel?

Throughout this chapter, and indeed this manual, the words 'channel' and 'channel address' will be used. The word channel is used two ways. First, it represents one relay on a 44462A multiplexer assembly. In other words, since the multiplexer assembly has 10 relays, we can refer to it as a 10 channel multiplexing assembly. The relays are numbered 0 through 9. Therefore, when we speak of channel 5 we are talking about relay number 5 on a specific 44462A assembly.

The second way the word channel is used is when we are referring to either an output bit or an input bit on an option 44465A Digital I/O Assembly. Generally though, the word "switch" will be used to indicate a digital output channel and the word "bit" to indicate an input channel.

## Channel Numbering and Addressing

Channel numbers are repeated on each 44462A (numbers 0-9) and 44465A (numbers 0-7) assemblies. Channel addresses, however, are determined by which slot the option assembly is plugged into plus the channel number. For an assembly in slot 1, channel 7 would be addressed as channel 17. The first digit stands for the slot number, and the second digit is the channel number. Channel 7 for an assembly in slot 2 would be addressed as 27. The following table shows the addressing scheme for the three different slots.

| Channel Number* | 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 |

* The digital I/O assembly uses only channel numbers 0 through 7.

# COMMANDS

The blue pages at the end of Chapter 3 list all of the commands the 3421A acknowledges. These commands are of two types: Standard and Advanced. The Standard commands provide the simplest method of programming the 3421A. Each command peforms a complete measurement task. An example of a Standard command is DCV2-17. This command sets up a channel list of channels 2 through 17, takes a DC voltage measurement from each channel, and stores the readings for future use.

## Standard Commands

The Standard commands are broken down into 5 groups: Voltmeter, Temperature, Counter, Channel, and Digital. Many of the commands allow you to specify one or more channels to make the measurement(s) from. This is called a channel list. In the following discussion, brackets—[]—are used to indicate the optional channel list. Letters x, y, and z represent the channel addresses. If a command shows the letter 'x' without brackets, it means that a channel must be specified with the command or an error will result. When the letter 'i' is used, it indicates a slot number; 0, 1, or 2.

- Voltmeter Standard Commands ([x,y,...z] is optional channel list)

  DCV[x,y,...z] — DC Voltage measurements on optional channel list.
  ACV[x,y,...z] — AC Voltage measurements on optional channel list.
  TWO[x,y,...z] — 2-Wire Ohms measurements on optional channel list.
  FWO[x,y,...z] — 4-Wire Ohms measurements on optional channel list.

- Temperature Standard Commands

  TEM[x,y,...z] — Temperature Measurements (for T-type thermocouples only) on optional channel list.
  REF[x] — A temperature measurement on the 44462A reference junction.

- Counter Standard Commands

  FRQ[x,y,...z] — Frequency measurements on optional channel list.
  TOT[x] — Totalize events from optional channel.

# COMMANDS (Cont'd)

- Channel (multiplexer, actuator, or digital) Standard Commands

| | |
|---|---|
| CLSx | – Close specified channel, whether multiplexer, actuator or digital output switch. |
| CLPx | – Close pairs (x and x + 10 or if x ! = 20 then x and x-20) |
| OPN[x] | – Open channel x,or if x is not sent then open all channels. |

- Digital Standard Commands

| | |
|---|---|
| REDi | – Read the digital inputs from slot 'i'. |
| WRTi,abc | – Write the decimal value (abc) to digital outputs in slot 'i'. |
| BIT x[y,...z] | – Read the digital input bit values from bits x,y.... and z. |

## Advanced Commands

The Advanced Commands provide more programming flexibility than the Standard Commands but they do not perform a complete measurement task. The Advanced Commands are generally used in groups to complete the task. For example, F1RA1Z1N6LS2-17;T5 would be used to perform the same task as the DCV2-17 Standard Command. Though too numerous to list here, the Advanced Commands are discussed in detail in the blue pages at the end of Chapter 3.

# COUNTER

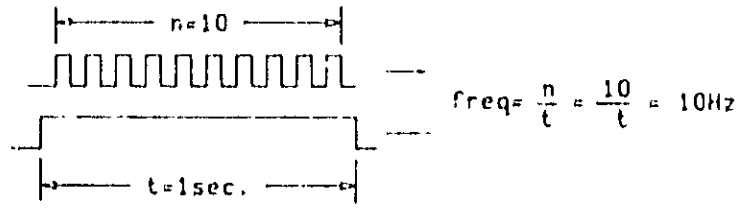
The 3421A internal counter is used to measure frequency to 10kHz or totalize events to 65535 counts. Signal inputs to the counter are through the 44462A multiplexer assembly or via the front panel INPUT terminals. Since the counter inputs are multiplexed through the same circuitry as voltage inputs, no other measurements can be made while the 3421A is measuring frequency or totalizing events. Once the measurement is complete, the 3421A is free to make other measurements.

## Frequency

The operation of the frequency counter is best understood by describing how the counter takes a measurement. If 'n' is the number of cycles of a signal that occurs during a known time period 't', then the frequency 'f' is determined by:

$$f = \frac{n}{t}$$

The counter measures the frequency of a signal by counting the number of complete cycles, n, that occur during a specified time period t. This is demonstrated in the following figure.




The time period 't' is known as the Gate time. It represents the time period that the counter spends counting the input signal. The longer the gate time, the greater the resolution of the measurement. Three gate times are available with the 3421A Advanced commands. These three gate times and their respective resolution are shown in the following chart.

| Advanced Command | Gate Time | Resolution (5 digits) |
|---|---|---|
| G-1 | .1 Sec | 10 Hz |
| G0 | 1 Sec | 1 Hz |
| G1 | 10 Sec | .1 Hz |

# COUNTER (Cont'd)

As a general rule, use the shortest gate time, G-1, for the highest frequencies. Use the longest gate time, G1, for the lowest frequencies.

The Standard command FRQ sets the 3421A to the frequency mode (F7) and 1 second gate time (G0). As with most Standard commands, the FRQ command can be associated with a Channel List, for example: FRQ|x,y,...z|. If a channel list is sent, the 3421A makes the measurements on the channels specified and stores the readings. All the readings will be sent to the computer in the order the readings were made.

If no channel list is sent, no channels will change and only one measurement will be made. If no channel relays are closed, the signal can be input through the 3421A front panel.

## 3421A COMMANDS:

| Standard | Advanced |
|---|---|
| FRQ\|x,y,...z\| | F7 Frequency<br>G-1 .1 Sec. Gate Time<br>G0 1 Sec. Gate Time<br>G1 10 Sec. Gate Time |

## Totalize

The totalize mode is used to simply count events. Each event is represented by a pulse sent to the 3421A. The maximum number of events that the 3421A can count is 65,535. The Standard command TOT is used to set the 3421A to the TOTalize mode.

Upon receipt of TOT, the 3421A clears its counter and begins counting. Keep in mind that once the 3421A is in the TOTalize mode, it will continue to count until the 3421A receives another command. If a TRIGGER command is sent to the 3421A, the TOTalize mode will be aborted and the 3421A will take a frequency measurement. While the 3421A is TOTalizing, the 3421A can be addressed to talk (see ENTER statement in chapter 3 or IND in Chapter 4) and it will send the current subtotal without resetting the counter.

# COUNTER (Cont'd)

The 44462A Multiplexing Assembly (option 020) is used to connect the signal to the Counter. Only one channel can be specified with the TOTx command. If 'x' is sent, and that channel is not a multiplexer channel, an error will be generated. Channel 'x' will remain closed until another command opens it.

## 3421A COMMANDS

| Standard | Advanced |
|---|---|
| TOT\|x\| | |

# DISPLAY

## How It Is Used

The 3421A display serves two main functions. First, at turn-on or reset (RS command) the display provides the result of the internal Self Test and the HP-IB address (if the HP-IB option is present and switched in). Second, the display is used to indicate any channels or digital output switches that are closed.

## Turn-on/Reset

At turn-on you will hear an internal relay 'click' as the all numbers in the 3421A turn on. This display will be on for about 1 second. Then, if any of the self tests fail, a number will light up in the display for about 1 second and the error indicator will turn on. Following this, a second relay 'click' is heard indicating that the self test has finished. If the HP-IB option (option 201) is installed and the HP-IB switch is 'in', the HP-IB address will be displayed next. After all of this, the 3421A will go to its turn-on state. The following chart shows the possible self test failures and the display number lit:

| Number Lit | Self Test Failed |
|---|---|
| 0* | Calibration RAM Checksum Error |
| 1 | ROM 1 Bad |
| 2 | ROM 2 Bad |
| 3 | A/D Slope Error |
| 4 | Microprocessor RAM Bad |
| 5 | Internal RAM 1 Bad |
| 6 | Internal RAM 2 Bad |
| 7** | Failed 10MΩ test (not within ± 20%) |
| 27 | Low Battery, the 3421A will shut itself off in three seconds. |

* Error 0 will occur if an option 44462A, 10 channel multiplexer is added or moved to a different slot after the 3421A was calibrated. This is because the temperature reference was not calibrated.

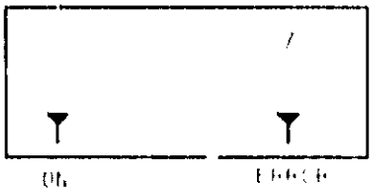
** Error 7 will occur if there is anything connected to the front panel input terminals or HCOM and LCOM on an installed 10 channel multiplexer assembly during self test.

# DISPLAY (Cont'd)

When the 3421A is reset by the RS command, it goes through its self test routine just as if it were turned on. The display will light up all numbers for one second, followed by an error indication if any self test failed. The HP-IB address, however, will not be displayed

## Do This:

Simulate an error by shorting the front panel input terminals on the 3421A and either cycling the LINE switch off and on or sending the RS command.



After all numbers light up on the display, the number 7 should appear for one second and the error indication should light.

## 3421A COMMANDS:

| Standard | Advanced |
|---|---|
| | RS Reset |

# Channel Display

Aside from the display being used to indicate errors during the self test, the display is used to indicate channel closures. The numbers lit on the display indicate channels or digital output switches that are closed. For example, if a 44465A Digital I/O Assembly is located in slot 01 and has output switches 2, 5, and 7 closed, the numbers 2, 5, and 7 will appear on the display. Furthermore, if a 44462A Multiplexer Assembly is located in slot 1, and DCV19 is executed, then channel numbers 2, 5, 7, and 19 will be displayed. This is because all these channels are closed.

## 3421A COMMANDS:

| Standard | Advanced |
|---|---|
| All but REF, OPN, and REDI | DN, UC, SI1, SI0 |

# HP-IL POWER DOWN/POWER UP

## Power Down

HP-IL Power Down can only be executed from the HP-41C/CV handheld calculator. Power down is used to put the 3421A in a low power standby mode. When the power down command is received by the 3421A, the complete status of the instrument is stored away in internal memory. The multiplexer and actuator (but not digital output switches) are left in the same state they were in previous to the command. In other words, a channel that was closed prior to Power Down will remain closed after Power Down. Digital Output Switches go to a high impedance (open) state.

## Power Up

When any information is sent through the HP-IL loop, the 3421A will power back up, assuming that a low battery condition did not occur. If any Multiplexer or Digital I/O assemblies are changed or reconfigured, or if the data stored is no longer valid, the 3421A goes through its turn-on routine. If nothing has changed since the 3421A powered down, it remains in the same state except for:

1. TOT, if it was on, will now be off.
2. All digital output channels will be cleared (high impedance).

# OPTIMIZING READING RATES

## Why Optimize

There are several reasons why you may want to optimize the rate at which readings are taken by the 3421A. Perhaps your system is being used to monitor a large number of points where a faster reading rate means a better picture of what is happening at a single point in time. Maybe you need to read quickly and not waste valuable computer time waiting for a measurement result. Whatever your reason for optimizing reading rates, the 3421A can solve many measurement requirements.

The maximum reading rate with the 3421A is influenced by many factors. These include the signal environment (line related and broadband noise, thermal gradients, etc.), the desired accuracy, and the type of measurement to be made. AC voltage measurements have a built-in 600mS settling delay. Resistance measurements can be made as fast as DC voltage measurements except on the 3 Mohm and 30 Mohm ranges where a settling time (20mS and 200mS respectively) is built in.

The speed and timing of the measurement process is dependent upon a number of factors. These include the number of digits of resolution selected (N commands), whether or not the autozero feature is enabled (Z command), and the selected function—DC volts, resistance, etc.

## Your Signal Environment

The signal that you are attempting to measure may be subject to power line frequency related noise and broadband noise which can interfere with your measurement. The 3421A works to minimize or reject this kind of noise by using a form of Analog-to-Digital (A/D) conversion called integration. Integration is a process where line related noise is averaged to zero over the time period of an integer number of power line cycles.

The measure of the ability of the voltmeter to measure a DC voltage in the presence of AC voltages (at power line frequencies) is called Normal Mode Rejection (NMR). The NMR of the 3421A is dependent upon the number of digits of resolution selected (N3, N4, N5). Greatest NMR (80db) is provided with 5½ digits of resolution but this also has the slowest reading rate. The 4½ digit mode provides 59 db of NMR while the 3½ digit mode provides virtually no noise rejection. Another important part of this process is to make certain that the 50/60 Hz switch on the rear panel is set properly: down for 50 Hz line frequency and up for 60 Hz.

# OPTIMIZING READING RATES (Cont'd)

## Autozero

The thermal stability of the measurement environment is also a very important consideration. If the 3421A is in a stable temperature environment, disabling the autozero function substantially increases the reading rate. There is very little loss of accuracy. Any range or function change results in an automatic autozero update which removes any accumulated offsets.

## The Fastest Reading Rate

The maximum possible reading rate on one channel occurs when 3½ digits of resolution is selected (N3), autozero off (Z0), any DC voltage function (F1, F3, or F4), 60Hz line frequency set on the rear panel switch, manual ranging (not autoranging), and a positive voltage measured. This assumes that the channel list is loaded with that one channel; for example: LS5-5.

The following tables show the 3421A reading speeds assuming the readings are stored in internal memory.

# OPTIMIZING READING RATES (Cont'd)

READINGS/SECOND

Repeat on one channel:

| | Z1F1 | Z0F1 | Z1F2* | Z0F2* | Z1F3/F4** | Z0F3/F4** | F6 |
|---|---|---|---|---|---|---|---|
| N5 | 2.26 | 4.08 | --- | --- | 2.26 | 4.12 | 1.05 |
| N4 | 15.85 | 23.92 | 0.4 | 0.4 | 15.85 | 24.31 | 1.05 |
| N3 | 30.96 | 38.56 | 0.4 | 0.4 | 30.93 | 38.31 | 1.05 |

Random Channel

| | Z1F1 | Z0F1 | Z1F2* | Z0F2* | Z1F3/F4** | Z0F3/F4** | F6 |
|---|---|---|---|---|---|---|---|
| N5 | 2.19 | 3.98 | --- | --- | 2.19 | 3.99 | .98 |
| N4 | 13.18 | 18.34 | 0.4 | 0.4 | 13.20 | 18.61 | .98 |
| N3 | 22.22 | 25.99 | 0.4 | 0.4 | 22.19 | 26.01 | .98 |

N5, N4, N3 = 5½, 4½, 3½ digit mode (respectively)
Z0, Z1 = Autozero off, on
F1 = DC Volts, F2 = AC Volts, F3 = 2-Wire Ohms, F4 = 4-Wire Ohms,
F6 = Temperature Measurements.

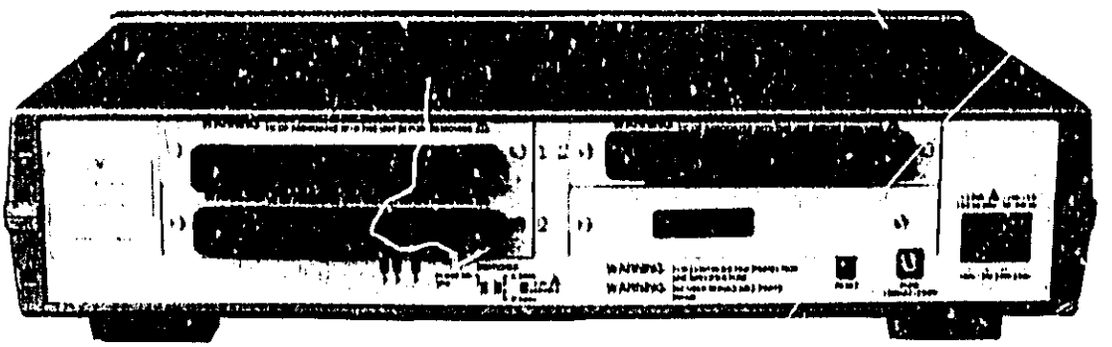
* There is a 1.8 second delay between AC voltage readings. Consequently, the reading rate can be stated as 2.6 seconds per reading.

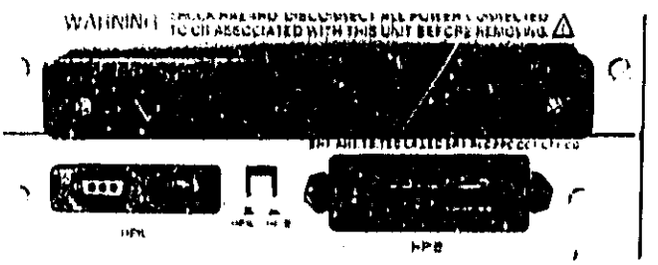
** Because of internal delays, the 3 MΩ and 30 MΩ ranges have reading rates of 2.1 Readings/Sec. and 1.6 readings/Sec., respectively.

# REAR PANEL

## What is on the Rear Panel?

The photo below is of the 3421A rear panel. The insert shows the 3421A with the optional HP-IB interface. Notice especially the line voltage option sticker, the HP-IL and/or HP-IB connector, and the rear panel control switches. Before plugging the 3421A into an AC power source, make certain that the option marked on the label coincides with the nominal line voltage in your area. The line voltage option for the 3421A may be changed only by qualified service trained personnel.





# REAR PANEL (Cont'd)

## The Reset Switch

The Reset switch on the rear panel is used to completely reset the 3421A. In the event of a failure where the front panel POWER switch cannot turn the instument off, this reset switch is used to remove all power to the instrument for as long as you hold in the switch. As soon as you release the switch, power will be reapplied to the instrument.

## The Rear Panel Control Switches

Of the eight rear panel switches, three are accessible from the rear panel. These switches are described below. Two of the switches that are not accessible are used for troubleshooting and the remaining three are not used. The switches are numbered from left to right.

Switches 2, 4, and 7 are not used.

Switch 3 is used to set the Power-on SRQ feature. When this feature is enabled, i.e. the switch is up, the 3421A will generate a service request to the system computer when the front panel LINE switch or rear panel Reset switch is cycled. Refer to REQUIRE SERVICE and SPOLL in Chapter 3 for more information.

Switches 1 and 6, at turn-on, forces the 3421A into Digital Signature Analysis routines for troubleshooting. Refer to 3421A Service Manual for troubleshooting procedures. These switches are not accessable from the rear panel.

Switch 5 is the 50/60Hz line frequency switch. This switch should be in the down position if a power line with 50Hz frequency is being used. The switch should be up for 60Hz line frequency. This switch changes the integration period (see optimizing reading rates) of the A/D convertor so as to obtain the greatest NMR. The reading rate is slightly lower (~ 17%) when 50Hz is selected.

Switch 8 is the Calibration Enable switch. When placed in the down position, calibration is enabled. Enabling the Calibration may result the loss of calibration of the 3421A. This switch should remain in the up position except when the 3421A is being calibrated by qualified service personnel.

**NOTE**

*On instruments with a serial number prefix of 2247A or lower, switches 1, 2, and 7 are not used and switches 4 and 6 are used for Digital Signature Analysis.*

# RESISTANCE MEASUREMENTS

## Measuring Resistance

The 3421A is capable of measuring resistances from 1 milli-ohm to 30 Mohms in six ranges. Resistance measurements may be made in either 2- or 4- wire ohms configuration. The illustrations below show how resistance measurements are made. A known current is supplied by the 3421A and flows through the unknown resistance. The DC voltmeter measures the resulting voltage across the resistor and calculates the resistance. The table shows the nominal current through the unknown resistance for the individual resistance ranges.

| Range | Current Through Unknown Resistance | Maximum Open Circuit Voltage |
|---|---|---|
| 300 Ω | 1 mA | 6.5 V |
| 3 kΩ | 1 mA | 6.5 V |
| 30 kΩ | 100 μA | 6.5 V |
| 300 kΩ | 10 μA | 6.5 V |
| 3 MΩ | 1μA | 4.5 V |
| 30 MΩ | 0.1 μA | 4.5 V |

Nominal Current Through Unknown Resistance

The 3421A is factory calibrated in the 4-Wire ohms mode. If most or all of your resistance measurements will be made in the 2-Wire ohms mode, the 3421A can be recalibrated for best accuracy in the 2-Wire mode. See the 3421A Service Manual.

There are two situations in which the 3421A may indicate a negative resistance: either a small voltage exists on the circuit under test or the 4-Wire SENSE and the INPUT leads are inverted from each other in the 4-Wire ohms mode.

# RESISTANCE MEASUREMENTS (Cont'd)

## 2-Wire Resistance Measurements

2-wire resistance (or ohms) measurements can be used when the resistance of the test leads is not critical. Generally, the larger the resistance being measured, the less you have to be concerned about the lead resistance. For example, if the lead resistance of each lead is 5 ohms (10 ohms total), and you are measuring a fixed resistance of 10k ohms, the introduced error is small (10/10000 = .001 = .1%). However, a lead resistance of 10 ohms becomes quite significant when measuring small resistances. Suppose you are using leads with a resistance of 10 ohms and attempt to measure the resistance of a temperature dependent resistor (RTD) that is rated at 100 ohms at 0 °C. Here we have two problems. First, the lead resistance will add a significant error to the reading, even at 0 °C. (10/100 = .1 = 10%). The temperature coefficient for this type of device is typically about .385 ohms/°C. This means that if the RTD is being used to determine the temperature of some environment, the 10 ohm lead resistance would cause an approximate 26 °C error in the measurement. The second problem that arises is that if the temperature of the RTD environment changes, we cannot accurately track the change. Such an application would be better suited to 4-wire ohms.

## 4-Wire Resistance Measurements

The use of 4-wire ohms measurements virtually eliminates the error caused by the test lead resistance. The current through the unknown resistance is the same regardless of the lead resistance but the voltmeter measures only the voltage across the resistance, not across the combined test lead and resistance. The 4-wire ohms mode is essential when the highest accuracy is desired.

## 3421A COMMANDS:

| Standard | Advanced |
|---|---|
| TWO(x,y,...z) — for 2-wire ohms — | F3 (use LS for channel list) |
| FWO(x,y,...z) — for 4-wire ohms — | F4 (use LP for channel list) |

# TEMPERATURE MEASUREMENTS

## Using Thermocouples to Measure Temperature

Because thermocouples are useful over a wider range of temperatures than RTD's or thermistors, they are frequently used in temperature measurements. The 3421A and its 44462A multiplexer option assembly are ideally suited for temperature measurement using thermocouples.

Supplied with this manual is -hp- Application Note 290 on Practical Temperature Measurements. Even if you are familiar with using thermocouples, you may want to read this Application Note. Read very carefully the section on the Reference Circuit as software compensation must be used with the 3421A. This will provide a basis for the following discussion. The Application Note also provides excellent suggestions for increasing the integrity of thermocouple measurements.

The 44462A multiplexer assembly for the 3421A utilizes an integrated circuit temperature sensor to determine the temperature of the isothermal terminal block. In performing a software compensated thermocouple measurement, the following steps must occur:

1. The voltage from the temperature sensor on the multiplexer assembly is measured. This voltage is used to compute the temperature of the terminal block which is known as the Reference Temperature. This step is performed automatically by the REF command.

2. Convert the terminal block temperature to a thermocouple Reference Voltage. The actual implementation of this step will depend on the type of thermocouple being compensated. It allows the use of several types of thermocouples to be used 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 (step 3). This step produces the icepoint compensation.

5. Convert the sum voltage (step 4) to a temperature.

Although these five steps may seem cumbersome they are actually very easy to perform under computer control. Complete examples, including conversion coefficients for all thermocouples, are provided in Chapters 3 and 4.

To simplify the matter even further, the 3421A was designed to automatically perform all of these steps for a T-type thermocouple. The answer returned will be in degrees C. With other thermocouple types, the 3421A can perform steps 1 and 3 but the system computer must do steps 2, 4, and 5.

## Measuring the Reference Temperature

The Reference Temperature can be measured with the REF command. A single channel should be specified with the REF command. For example, if you will be measuring the thermocouple voltage from channel 5, you will need to also execute the command REF5. This will give the Reference temperature of the terminal block in slot 0 which is where channel 5 is located. If no channel is specified, then the REF command will simply default to the 44462A assembly where a multiplexer channel is closed. If there are no multiplexer channels closed, the REF command defaults to the 44462A assembly with the lowest slot number. If there are no 44462A assemblies in the 3421A, an error will be generated. See Require Service in Chapter 3 for error information.

## Using T-type Thermocouples to Measure Temperatures

The TEM command is used to automatically perform a software reference junction compensated conversion for T-type thermocouples. As with most Standard commands, TEM can be used with a channel list. The TEM command makes use of the REF command to obtain the Reference Temperature. The Reference temperature will be taken on the same option board as the specified channel, if a channel is given with TEM. If no channels are specified, then the Reference Temperature measurement will be made on the 44462A multiplexer assembly where a multiplexer channel is already closed. If no multiplexer channels are closed, the Reference measurement will be made on the 44462A assembly in the lowest numbered slot. If there are no 44462A assemblies, an error will be generated.

### 3421A COMMANDS

| | Standard | Advanced |
|---|---|---|
| Temperature | TEM[x,y,...z] | F6 |
| Reference | REF[x] | |

# TEST/RESET

## What it Does

At power on or Reset (RS command), the 3421A performs a series of 8 checks on the digital logic and A/D converter. If any of these checks fail, the ERROR indicator will turn on in the display and the 3421A will attempt to interrupt the computer (see Require Service in chapter 3). The sequence of self tests are as follows:

1. Microprocessor internal RAM check. The microprocessor has internal Random Access Memory that is tested.

2. ROM Checksum. Both ROM's (Read Only Memory) are tested for proper checksums.

3. Calibration RAM Checksum*. The calibration RAM is tested for proper checksums.

4. Analog-to-Digital (A/D) Slope test. This test is for the A/D converter.

5. External RAM Tests. The two RAMs, external to the microprocessor, are tested

6. 10 MΩ Test. This checks the 100:1 divider inside of the A/D input hybrid.

After the self tests have been performed, the 3421A will light all channel numbers in the display for about 1 second. After this, if any failures occurred during the self tests, a number will light up to indicate the failed self test. These numbers are as follows:

| Number lit | Self Test Failed |
|---|---|
| 0* | Calibration RAM checksum error. The calibration of the 3421A is suspect. |
| 1 | ROM 1 bad. |
| 2 | ROM 2 bad |
| 3 | A/D Slope error. This would indicate some error in the A/D converter circuitry. |
| 4 | Microprocessor RAM bad. Replace the microprocessor. |
| 5 | External RAM 1 is bad. This is one of the RAM's external to the microprocessor. |
| 6 | External RAM 2 is bad. This is the second RAM external to the microprocessor. |
| 7** | Failed the 10 MΩ self test (it is not within ± 20%) |

* Error #0 will also occur if a 44462A 10 channel multiplexer assembly is added or moved to another slot that is not calibrated for the temperature function.

** Error #7 will occur if there is anything connected to the front panel input terminals or to HCOM and LCOM on an installed multiplexer assembly during the self test.

# TEST/RESET (Cont'd)

After the self test, the 3421A will go to the following states:

- All 44462A option board relays are open.
- All 44465A digital output bits are cleared (high impedance state).
- DC volts function, Autorange on, Autozero on, 5½ digits of resolution.
- Counter set to 1 second gate time.
- The 3421A monitors the rear panel switches and acts accordingly.
- The channel list is set to all available multiplexer channels from the lowest number to the highest number.
- Request service from the computer if self test failed or Power-on SRQ enabled (rear panel switch).

## 3421A COMMANDS:

| | Standard | Advanced |
|---|---|---|
| Reset | | RS |

# VOLTMETER

## The Internal Voltmeter

The 3421A internal voltmeter provides many features not commonly found in a data acquisition voltmeter. The voltmeter provides 3½ to 5½ digit resolution for DC voltage and 2- or 4- wire resistance measurements, and 3½ to 4½ digit resolution for AC voltage measurements. Of course the voltmeter is used in making temperature measurements. The voltmeter offers DC voltage measuring performance of 1uV sensitivity to 300 volts maximum. AC voltage measurements can be made with 100uV sensitivity to 30 volts maximum with a bandwidth of 30Hz to 1kHz. Optional divider resistors are available for measuring AC voltages up to 300 volts peak. Resistance measurements are from 1mΩ sensitivity to 30MΩ (full scale).

By selecting the number of digits of resolution and using the autozero feature (discussed later), the voltmeter allows you great flexibility in measurement speed and accuracy. Up to 30 readings per second (one channel only with a 10 channel multiplexer assembly installed) can be made with the voltmeter in the 3½ digit mode. The autorange feature of the voltmeter allows fast measurements over a wide dynamic range.

To lower your cost of ownership, the voltmeter is calibrated electronically. There are no internal adjustments and the calibration of all functions is accomplished without removing any covers. The self test function verifies most of the internal circuitry of the 3421A indicating proper operation of the voltmeter.

### Autozero

Autozero is a function that allows you to enable or disable the internal zero-correction circuitry of the voltmeter. Autozero on, which is the default condition, insures that any offset errors generated internal to the voltmeter are continuously nulled with each reading. This renders the most accuracy. Turning autozero off will substantially increase the reading rate but with a tradeoff of long term stability and accuracy.

With the autozero function enabled, the voltmeter takes two measurements per reading: a "zero" measurement and a measurement of the input signal. The internal processor takes the algebraic difference of the two readings and this is the value that is sent to the computer. The voltmeter makes the zero measurement by disconnecting the input relay and then shorting the internal input circuitry to circuit common. It then switches back for the input signal measurement.

With autozero turned off, whenever a new function or range is selected, the voltmeter immediately takes one zero measurement and stores the result in internal memory. Subsequent measurements of the input signal use this stored zero reading for correction. Since only the input signal is measured, the reading rate nearly doubles.

There are some applications where disabling autozero is advantageous. With autozero off, the reading rate increases. This would be important in applications where measurement speed is critical. Furthermore, the voltmeter input circuitry remains in a completely static state with autozero off. This is useful when making measurements in extremely high impedance circuitry where the internal switching of the voltmeter might affect the reading accuracy.

Since the input circuitry for AC voltage measurements is capacitor coupled, it is not necessary to correct for DC offsets. Therefore, the autozero function is only used to null offsets in the A/D converter. Turning the autozero off for AC volts eliminates the zero reading of the A/D converter and results in a faster reading rate.

### Calibration

It is beyond the scope of this section to provide the complete calibration procedures for the 3421A. Refer to the 3421A Service Manual for detailed information.

Briefly, Calibration is accomplished by simply applying a stimulus, i.e., voltage, resistance, etc., and informing the 3421A of the absolute value of that stimulus. Let's call this known value "A". The 3421A then takes ten readings of the input and averages them together. The average is subsequently compared to "A". The 3421A then computes a "Calibration Constant" which is stored in its internal memory. This "Calibration Constant" is used to correct all subsequent readings.

## Measurement Functions

The 3421A internal voltmeter is capable of measuring DC voltages, AC voltages, and resistances in either 2- or 4- wire mode. If you have special requirements in making voltage or resistance measurements, be sure to read the sections elsewhere in this chapter on Optimizing Reading Rates, Autozero, Number of Digits of Resolution, and Triggering Modes.

### DC Voltage Measurements

DC Voltage measurements with the 3421A internal voltmeter are simple and straightforward. The Standard Command "DCV" can be used to take DC voltage measurements from the front panel if no channel relays are closed. With the optional channel list, DC voltage measurements can be made from the specified channels.

Of course the Advanced command F1 with associated ranging and triggering commands can also be used. When using the Advanced commands, you can have more

flexibility in your measurements. For example, you can turn autozero off to increase the reading rate. Similarly, you can select the number of digits of resolution (3½, 4½, or 5½). Read the section in this chapter on Optimizing Reading rates before attempting to use the Advanced commands.

## AC Voltage Measurements

Like DC voltage measurements, AC voltage measurements are straightforward. Use the ACV Standard Command with the optional channel list. The Advanced Command for AC voltage is F2. The number of digits of resolution can be either 3½ or 4½.

The 3421A uses an Average responding AC to DC converter for AC voltage measurements. This means that the voltmeter measures the average value of the positive portion of the input and returns it as an RMS equivalent for a pure sine wave. Inputs that are non-sinusoidal, such as rectangular waves, will result in measurement errors.

## Resistance Measurements

An entire section is devoted to resistance measurements earlier in this chapter. Please refer to it for information on resistance measurements.

## Number of Digits Of Resolution

With the 3421A internal voltmeter you have a choice in the number of digits of resolution. This choice provides several alternatives and tradeoffs. For example, 3½ digits of resolution provides the fastest reading rate but it also has the least amount of noise rejection. At 5½ digits of resolution, the noise rejection is the greatest but the reading rate is much slower.

Changing the number of digits of resolution actually changes the "Integration Time" which determines the reading rate. Integration is a method of Analog-to-Digital (A/D) conversion where the effects of power line related noise averaged to zero over a period of an integral number of power line cycles (PLC's). The integration time is not the same as the time required for one measurement. Rather, the integration time is the time, in PLC's during which the input signal is sampled by the voltmeter. For DC Voltage measurements at 4½ digits of resolution, the time required for one integration cycle is one PLC: 16.66 mS at 60Hz line frequency or 20 mS at 50Hz. In the 3½ digit mode, the integration time is 0.1 PLC.

# VOLTMETER (Cont'd)

Normal Mode Rejection (NMR) is the measure of the ability of a voltmeter to accurately measure DC voltages in the presence of AC voltages at power line frequencies. The 3421A voltmeter has much better NMR at 4½ digits of resolution than it does at 3½ digits (59db vs. 0dB). The greatest amount of NMR is available with 5½ digits of resolution: 80 dB. In this mode, ten (10) readings are taken at 1 PLC integration time and averaged together.

## Ranging

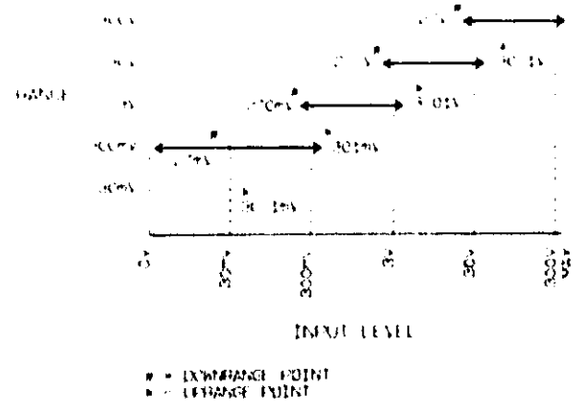
Selecting the proper range on the 3421A voltmeter may be done either automatically - called autoranging - or manually. All of the Standard Commands utilize autoranging. The fast autoranging in the voltmeter means that signals with a wide dynamic range, such as from channel to channel, are made quickly.

### Autoranging

Autoranging in the 3421A voltmeter is done by taking readings in the 4½ digit mode. Measurements are made on successive ranges until one range is found where the reading is between full scale (30100 counts) and approximately 9% of full scale (02700 counts).

### Autorange Hysteresis

In the autorange mode, the voltmeter will uprange (go to the next higher range) when the reading exceeds (±) 30100 counts. Conversely, it will downrange (go to the next lower range) if the reading decreases below (±) 02700 counts. These figures assume a 5½ digit mode. These numerical autorange points are irrespective of decimal point placement. The difference between the two points is called the autorange hysteresis. This is illustrated in the following figure for DC volts. Autorange hysteresis for other functions is similar.



## Manual Ranging

The 3421A is placed in the manual range mode by executing any of the manual range commands or the RA0 command. It can be returned to autorange with the RA1 command.

## Valid 3421A Voltmeter Ranges

The following chart shows the various ranges available in the voltmeter.

| Function | Ranges | Programming Code For Manual Ranging |
|---|---|---|
| DC Volts | .3V,3V,30V,300V | R-1,R0,R1,R2 (respectively) |
| AC Volts | 3V,30V | R0,R1 |
| Resistance | 300Ω,3kΩ,30kΩ 300kΩ,3MΩ,30MΩ | R2,R3,R4,R5,R6,R7 |

If the voltmeter is in the manual range mode, the result returned to the computer will be +9.99999E+9 (5 1/2 digit mode) when the input is greater than the particular range can measure.

# Triggering

To trigger the voltmeter simply means that you instruct it to take a measurement. Of course, this assumes that you have previously set up the voltmeter for the type of measurement with other commands. There are several methods of triggering the 3421A voltmeter. The Standard Commands trigger the voltmeter automatically. However, the advanced commands allow you to trigger the voltmeter in four (4) different ways. These are explained below.

## Standard Commands

The Standard Commands DCV, ACV, TWO, FWO, TEM, REF, FRQ, and TOT program the respective measurements and then execute a software trigger (see T3 under Advanced commands). The software trigger causes the voltmeter or counter to take one reading from each channel specified in the channel list. If no channel list is sent with the command, one reading will be taken from a previously closed channel. If no channels are closed, the command can be used to make measurements from the front panel input terminals.

# VOLTMETER (Cont'd)

## Advanced Commands

The set of Advanced Trigger Commands include: T0, T1,T2, T3, DTix.

T0 – T0 is for hold (don't trigger) but enable the channel list scan and reading storage. In other words, when T0 is asserted, the voltmeter will not take any readings but will prepare the 3421A for readings from the channel list. To initiate the measurements, execute an interface TRIGGER command (see Chapters 3 and 4).

T1 – T1 sets the voltmeter for internal trigger. This means that the voltmeter will trigger any time you ask for a reading, such as using the ENTER command (see Chapter 3) or IND command (see Chapter 4). T1 will not open or close any relays.

T2 – T2 is a software trigger and causes the 3421A voltmeter to take one measurement only. T2 will not open or close any channels.

T3 – Trigger command T3 is used to initiate the measurements on the channel list and store those readings. Note that if F0 (no measurement function) is asserted when T3 is executed, an error will occur since the 3421A was not told what type of measurement was to be made.

DTix – The Digital Trigger command is used to implement an external trigger. DT will cause a T3 trigger when digital input bit 'x' on the digital I/O option assembly in slot 'i' goes LOW.

# CHAPTER

# 3

# Chapter 3
# BASIC Language Programming

## Introduction

The speed and data handling capabilities of todays desktop computers support the 3421A in a Data Acquisition/Control system. In this chapter you will learn how to use those powerful desktop computers to program and control the 3421A. Be sure that you have read through Chapter 2 of this manual before starting this chapter. You will need to understand the operating characteristics of the 3421A before you begin programming it.

### Scope

The descriptions presented in this chapter are in general terms to optimize the flow of information regardless of the type of computer you are using. This means that both the inexperienced user as well as the experienced programmer will be programming the 3421A efficiently and productively with minimum instruction time. There are, however, many example programs given to enhance the discussion, all of which are given in the enhanced BASIC programming language such as the -hp- Model 85 Desktop computer uses.

## Trying Out a Command

Before we actually begin the programming discussion, let's look at some simple examples that demonstrate how easy it is to program the 3421A. First, make certain that your 3421A is connected to a computer through either the HP-IL interface or the HP-IB interface. Chapter 7 of this manual gives interface connection instructions. Don't forget to turn on both the 3421A and the computer.

If you don't have one of the computers specified in the following example, read through this section anyway as it provides a basis for later discussions. Consult the I/O programming manual for the computer you are using for information on sending and receiving information through the interface.

Now, have the 3421A display a number. Using the chart below as a guide, enter the command exactly as shown, replacing "x" with a number from 0 to 29 (i.e., DN5). After you execute the command, the number should appear on the 3421A's display.

| Interface/Computer | Type the Message | Press |
|---|---|---|
| HP-IL, HP-85 | OUTPUT 901;"DNx" | [END LINE] |
| HP-IB, HP-85, 9845, 9826 (BASIC) | OUTPUT 709;"DNx" | [EXECUTE] (on the -hp- 85 press, [END LINE]) |

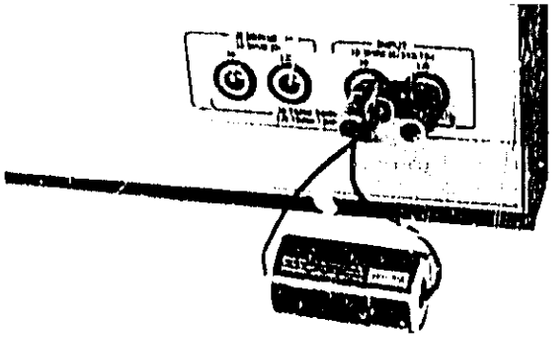
In the OUTPUT statements, the letters DN are called a command code and represent the message: Display Number x. The numbers in the 3421A display represent channel numbers. We will learn more about this later. At the end of this chapter are several blue pages that describe each of the command codes the 3421A will respond to, and how they are used. The following program will sequentially display each number from 0 to 29.

```
10 ! -HP- 85 version
20 ! HP-IL Example
30 ! 3421A at address 901
40 FOR X=0 TO 29 STEP 1 ! This line sets up the loop counter
50 OUTPUT 901 ;"DN";X ! 'DN' is sent followed by value 'X'
60 WAIT 500 ! Wait to see the number
70 NEXT X
80 END
```

Let's try another example. Connect a battery to the 3421A front panel INPUT terminals. Since a battery is a DC voltage, tell the 3421A to make a DC voltage measurement. This is done with a DCV command:

| Interface/Computer | Type the Message | Press |
|---|---|---|
| HP-IL, HP-85 | OUTPUT 901;"DCV" | [END LINE] |
| | ENTER 901; A | [END LINE] |
| | DISP A | [END LINE] |
| HP-IB, HP-85, 9845, 9826 (BASIC) | OUTPUT 709;"DCV" | [EXECUTE] or [END LINE] |
| | ENTER 709; A | [EXECUTE] or [END LINE] |
| | DISP A | [EXECUTE] or [END LINE] |

Note. In the examples above, the 901 and 709 are the HP-IL address and HP-IB address, respectively. Addresses will be discussed in detail later. For now, simply perform the exercise.



The value displayed is the measured battery voltage. The command DCV is called a Standard Command and performs a specific measurement task.

# HP-IL vs. HP-IB

With the 3421A you have a choice of computer interfaces. The Hewlett-Packard Interface Loop (HP-IL) is standard with the 3421A and is ideal in low cost, low power, and medium distance applications. An optional HP-IB* interface is also available for the 3421A. From the programmers viewpoint these two interfaces are very similar and differ mainly in the instrument addressing.

Appendix B in this manual gives a brief description of the HP-IL and HP IB interfaces. Chapter 7 of this manual gives interface connection instructions.

When the computer tells a particular instrument to send data over the interface, we say that the instrument has been "Addressed to Talk". Likewise, when the computer tells an instrument to receive data or instructions, the instrument is said to be "Addressed to Listen". The 3421A is capable of both "Talking" and "Listening". These terms are used throughout this chapter to describe various operations. There can be only one instrument addressed to talk at any one time.

## Information Transfer

When operating with the HP-IL interface, most 3421A commands will "Hold-up" the computer until all readings have been taken. This feature makes Data Ready SRQ unnecessary for most measurements (Data Ready SRQ is described later in this chapter). In other words, suppose you have a 3421A, with three 44462A 10 channel multiplexer assemblies, programmed to take 30 readings; one reading from each channel. With a reading rate of approximately 2 readings per second, 15 seconds

*HP-IB (Hewlett-Packard Interface Bus) is Hewlett-Packard's implementation of IEEE Standard 488-1975 and ANSI MC1.1.

are required to take all 30 readings. The computer will not be able to perform ANY task during this 15 second period while the 3421A is making the measurements. This is demonstrated in the following program.

```
10 ! EXAMPLE
20 OUTPUT 901 ;"DCV0-29"
30 FOR I=0 TO 29
40 ENTER 901; A(I)
50 DISP A(I)
60 NEXT I
70 END
```

After line 20 is executed, the 3421A will hold-up the computer while it takes the 30 readings.

The 3421A commands that do not hold-up the computer are: digital monitor commands MN, MH, and ML; TOTalize function; and Digital Trigger (DT). An example will be given later in this chapter demonstrating the DT command and interrupting the computer.

The advantage of this feature comes when you are using other devices with the 3421A. For example, let's say you are using the 3421A as a scanner - not using the internal voltmeter - with some measuring device such as a power meter. You would first close a channel on the 3421A and then trigger the power meter. Triggering cannot occur though, until the 3421A has closed the channel and freed the computer. In other words, the power meter is prevented from triggering until the 3421A relay is known to be closed, thus preventing false measurements.

With the HP-IB option and HP-IB selected, this computer hold-up feature is switch selectable. Access to the switch, however, is gained by removing the HP-IB option cover and should be done by service trained personnel only. With Buffered Transfer disabled (switch up, normal position) the 3421A acts much the same as the HP-IL interface, holding up the computer until all measurements are taken. Buffered transfer disabled (switch up) is the factory setting of this switch. With the switch in the DOWN position (buffered transfer enabled) the computer is released while the 3421A takes its measurements. This mode provides the fastest transfer of information between the computer and the 3421A.

You should be aware however, that if any of the digital monitor modes (MN, MH, ML, or DT) are in effect in the 3421A, any communication through the interface will cause the mode to be aborted. That is to say, if the 3421A is waiting for a Digital Trigger (DT) and the computer or another instrument sends any commands or data through the interface, the 3421A will abort the Digital Monitor and will no longer respond. It will need to be reprogrammed for that mode.

Moreover, when you have the HP-IB option in the 3421A and are using the 3421A in one of the Digital Monitor modes, i.e., MH, ML, MN or DT, the 3421A MUST be set to unlisten. This is in order for the 3421A to interrupt the computer via the SRQ interrupt. For the -hp- 85 and 9826A (BASIC) this would take the form:

```
SEND 7 ; UNL
```

Other computers will use a different command syntax. Two examples using this command are shown in the Require Service section later in this chapter.

## Buffered Transfers

Buffered transfers are enabled and disabled by HP-IB switch segment #6. This switch is accessed by removing the rear panel HP-IB option cover and should be done by qualified service trained personnel. When the switch is up (toward the pc board), buffered transfers are disabled (factory preset). When the switch is down, buffered transfers are enabled.

When is it appropriate to enable buffered transfers? Perhaps this question is best answered by a discussion of what buffered transfers are, and a limitation that they have. When buffered transfers are NOT enabled, and several commands are sent to the 3421A, each command is executed as it is received. The computer waits for the 3421A to execute the command that was just sent before sending the next command. Thus, the computer is not able to perform any other task until the 3421A executes the last command in the string. The 3421A holds up the computer by delaying the HP-IB handshake (i.e., the 3421A does not assert the NDAC handshake line until it has executed a command). Furthermore, the more commands sent, the longer the computer will be held-up.

When buffered transfers are enabled, the 3421A stores commands it receives in a buffer (up to 39 bytes). The computer is released to perform other program tasks as soon as the buffer storing is complete. The commands are then executed one after the other from the buffer. Hence, the computer does not wait for the 3421A to execute the buffer contents. As the 3421A executes the commands from the buffer, results are stored and then transferred to the computer when requested. Typically, this would be done using a Data Ready SRQ programming technique.

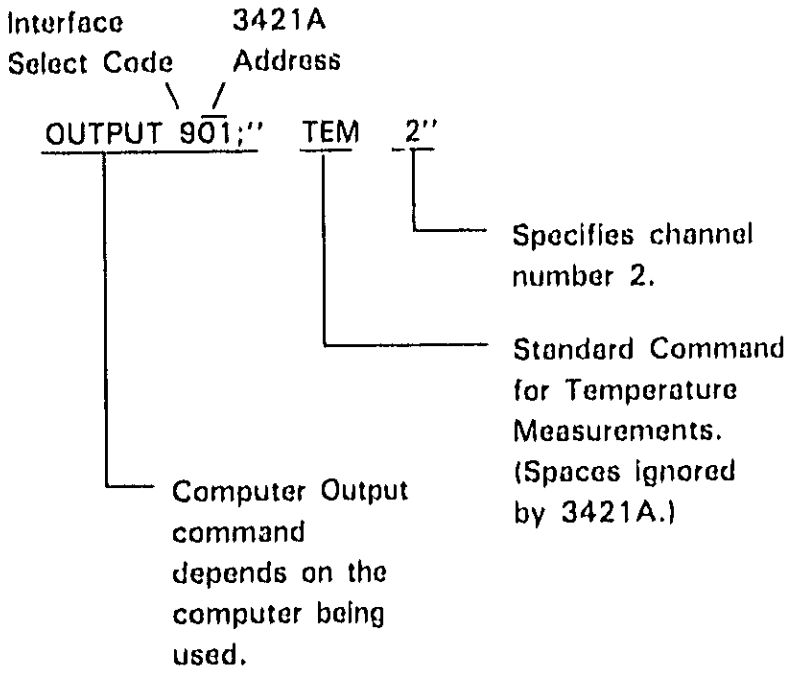
A limitation of buffered transfers is that different types of readings cannot be combined in the buffer. For example, do not specify a voltage and temperature measurement in the same command string. Furthermore, once a measurement is taken in the buffered transfer mode, the results should be retrieved before another measurement is taken.

The buffer size of 39 bytes should be more than adequate for the vast majority of applications. However, in instances where a string of commands exceeds 39 bytes, the buffered transfer mode is not recommended. If it is used, the computer will again be held-up once the buffer is full. In other words, it will defeat the benefits derived from using the buffered transfer mode.

## Addressing

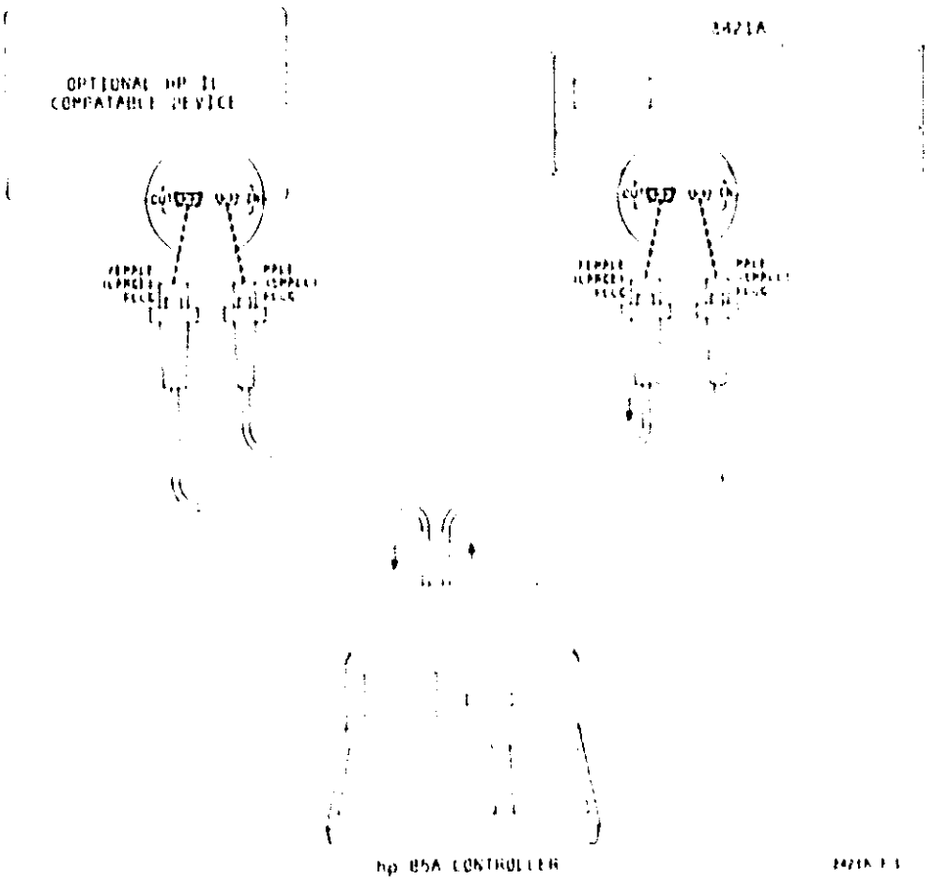
Each instrument that you connect to the interface, whether it be HP-IL or HP-IB, has a unique "address". The address provides a convenient way for the computer to send or receive data from a particular instrument even when there are several connected together.

In earlier examples, an instruction such as OUTPUT 901 (HP-IL) or OUTPUT 709 (HP-IB) was used to send a message to the 3421A. The three digit number, 901 or 709, is used to specify the address of the 3421A. The first digit (9 or 7) is called the interface select code (isc). The isc for the HP-IB interface is 7; for the HP-IL interface it is 9. The remaining two digits, called the instrument address, are used to specify the 3421A - or any other instrument - connected to the same computer interface.



## HP-IL Addressing

The computer automatically reassigns addresses to each instrument connected in the loop. This is called "Autoaddressing". Addresses are assigned sequentially to instruments in the loop in the direction of information flow. Refer to the HP-IL diagram below. The first device in the loop after the controller has an address of "1". The second device will have an address of "2", the third device an address of "3", and so on through the loop. A maximum of 30 devices, including the computer, may be connected in the loop. The 3421A may be connected anywhere in the loop and will be autoaddressed accordingly.




All examples in this chapter assume the 3421A is the only device connected to the computer HP-IL interface. Therefore, when autoaddressed, the 3421A will have an address of 1. Also, the -hp- 85 desktop computer with an 82938A HP-IL interface is assumed to be the computer used in the examples. The 82938A HP-IL interface has an interface select code of "9", therefore, the 3421A will be addressed at 901.

## HP-IB Addressing

The 3421A with HP-IB option (Option 201) has a switch selectable HP-IB/HP-IL interface.

The HP-IB address for the 3421A is determined by switch settings on the HP-IB option board. The 3421A has a factory preset address of 09. If the address needs to be changed, a qualified service trained technician will find the necessary information in Chapter 8 of this manual. In the examples where HP-IB addressing is demonstrated, the address will be 709. This refers to the computer HP-IB interface select code "7" and the 3421A address of 09. Note however, that if the rear panel switch is set for HP-IL, the addressing will follow the Autoaddressing constraints of HP-IL and will ignore the setting of the HP-IB address switches.

# Sending Instructions to the 3421A

Command codes are used to instruct the 3421A to perform a specific measurement or task. At the end of this chapter are several blue pages that provide a description of all of the commands the 3421A recognizes and responds to. Two categories of commands are provided,

A. Standard Commands set up the 3421A and then complete a measurement task For example, the command DCV2,7-9 causes the 3421A to take DC Voltage measurements on channels 2, 7, 8, and 9, and store the readings in its internal memory. One command causes a complete measurement task to be performed. The Standard Commands make programming easy.

B. Advanced Commands provide more flexibility than the Standard commands but they do not perform a complete measurement task. Individual commands are used to perform only one aspect of a measurement.

The Standard Commands are conveniently provided for the 3421A to ease the task of programming. As a result, most of the examples in this chapter will use the Standard Commands. The Advanced Commands are available to those users who wish to tailor their system for particular requirements.

## Procedure

Decide what task or measurement you want the 3421A to perform and determine the appropriate command. For example, if you are making temperature measurements (using T-type thermocouples) use the TEM command. If the thermocouple is connected to channel 2 in the 3421A, execute the command TEM2. The following message would be sent:

```
OUTPUT 901;"TEM2"
```

### Sample Problem

The previous illustration shows how to send the command to take a temperature measurement from channel 2. Suppose though, as will probably be the case, you have more than one measurement to make. They don't have to be temperature measurements, they could be voltage, resistance, or frequency measurements. The 3421A Standard Commands allow you to specify a group of channels, called a channel list, for the command.

To illustrate, assume you have T-type thermocouples connected to channels 2 through 8 and channel 14. The one command:

```
TEM2-8,14
```

will cause the 3421A to take temperature measurements from those eight channels and store the measurements internally. The complete command, along with the OUTPUT statement is:

```
OUTPUT 901;"TEM2-8,14"
```

Later in this chapter, you will learn to read back those eight temperature readings. For now, just remember that they are stored in the 3421A's internal memory. Up to 30 readings could be stored in this manner.

## Programming Hints

Make certain that you have read the paragraphs under HP-IL vs. HP-IB. These paragraphs deal with addressing and certain practices and exceptions that you will need to understand when programming.

When using the channel list the measurements are taken sequentially and stored. In other words, as in the previous example, channel 2 is measured first and the reading stored. Next, channel 3 is measured and its reading stored. This pattern continues for each channel until finally, channel 14 is measured and that reading stored.

Later, when you want to read back those measurements, the temperature from channel 2 will be returned first, followed by the temperature from channel 3, then 4,... and finally 14.

The series of channels specified in a channel list must follow these rules.

a. The default channel list (asserted at power on or reset) consists of all multiplexer channels 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 a so be loaded with digital input bit numbers by the BIT command. See chapters 5 and 6 for more information on the channel list.

b. Channel addresses are separated by commas. However, a dash may be used to signify a contiguous set of channels. When using Advanced Commands, any command that specifies a channel must be separated from subsequent commands by either a colon (:) or a semicolon (;) but not a comma. For example: F1RA1Z1N5LS5-9;T3. If the last character in the command string is a comma, an error will be generated.

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

d. The mnemonic determines what type of channel can be loaded into the channel list. In other words, if channel 1 is configured as an actuator channel, 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 is generated (see SPOLL) and the command is aborted. If channels x-y are received and some channels in between and including x and y are the wrong type of channels for the command, they are not loaded into the list and the error message is not sent. The remainder of the channels are loaded into the list.

e. Leading zeros are ignored, that is, DCV00019 means DCV19.

f. All syntax following a decimal point is ignored except for commas, dash, semicolon, colon, Carriage Return (cr), or Line Feed (lf). DCV2.3 means DCV2.

g. Exponents are not allowed and cause a syntax error. The command is aborted.

h. All lower case letters are interpreted as upper case. Blanks and the plus (+) sign are ignored. Commas (,), colons (:), and semicolons (;) are used as terminators. All other punctuation give a syntax error. In other words, Dc V 21 is the same as DCV21.

i. Terminators are required after any command (Standard or Advanced) that either specifies a channel or a decimal value, when that command is to be followed by another command. For example, the 'Mx' command is used to set the SRQ mask. This command can have a decimal value 'x' of between 0 and 255. Therefore, this command must be followed by a terminator if another command is to follow it; e.g.,

OUTPUT 901; "M1;T0". Valid terminators are a colon (:), a semicolon (;), a Carriage Return or Line Feed; but not a comma (,).

## Receiving Data From The 3421A

The 3421A has the ability to talk to the computer or other instruments, giving the results of measurements or status information. The computer must tell or "address" the 3421A to talk in order for it to send information.

Example. In the last section we saw how to send a command for a temperature measurement on channel 2. Now we want to read back the measured temperature. The ENTER statement is used.

```
10 OUTPUT 901 ;"TEM2" ! From a previous section
20 ENTER 901 ; A
30 DISP A
40 END
```

The 3421A is addressed to talk by the ENTER 901 command. The measured temperature is stored in the variable A and displayed on the computer's display. Remember that the actual computer syntax used (i.e. ENTER, OUTPUT, DISP, etc.) is dependent on the computer you are using and may be different than the the examples given in this manual. You should refer to your computer's I/O manual for specific information.

You also learned in the last section how measurements could be made on several channels using the channel list with a command. To read back those measurements, you will need one variable for each channel. Two sample programs are provided to illustrate how that can be done.

```
10 OUTPUT 901 ;"TEM2-8,14" ! From previous section
20 ENTER 901 ; A,B,C,D,E,F,G,H
30 DISP A,B,C,D,E,F,G,H
40 END
```

OR

```
10 OUTPUT 901 ;"TEM2-8,14" ! From previous section
20 FOR I=1 TO 8
30 ENTER 901 ; B(I)
40 DISP B(I)
50 NEXT I
60 END
```

In the first example, each reading is stored in a seperate variable. An array is used to store the readings in the second example. Remember that in some computers you

may have to dimension the array.

## Output Format

Measurement data is sent by the 3421A as 13 bytes in the following format (5 ½ digit mode):

| | |
|---|---|
| Measurement: | ± d.ddddd E ± d CR LF |
| Error: | -8.88888E + 8 CR LF |
| Overload: | + 9.99999E + 9 CR LF |

Digital data is sent as:

| | |
|---|---|
| Digital: | ddd CR LF (where $0 \leq ddd \leq 255$ decimal) |
| Digital Error: | 888 CR LF |

The character "d" represents a single digit. CR and LF are Carriage Return and Line Feed, respectively.

## Readings Output Format

Readings are sent as indicated above. The exponent is the same as the voltmeter range (unless the measurement is temperature or frequency). In other words, the reading + 1.23456E-1 means the measurement was taken on range R-1 (.3 volt) and the measured value is .123456 volts. If the measurement is entered into a numeric variable the measurement will be adjusted to eliminate the exponent. Refer to the Advanced Commands for more information on range codes. The number of digits following the decimal point is the same as the number of digits of resolution asserted. This means that if you have 3 digits of resolution asserted (N3), the reading will be output as: ± d.ddd E ± d. This change of output digits is also true for errors.

**Error Format.** The -8.88888E + 8 indicates an error and will be sent in place of the first reading after the error occurs. Bit 5 of the Status Register will also be set, see SPOLL later in this chapter. Conditions which will cause the error message are:

1. Hardware error
2. Calibration error
3. Command syntax not understood
4. Can't execute command
5. Low battery
6. Self Test failed

The error message will not be sent if the status byte is read (SPOLL or SR commands) before the 3421A is addressed to talk. In this case the reading, if available,

will be sent. This is shown in the following two examples. The first example shows the typical command and data read sequence. The second example shows how to read the status byte prior to requesting data.

```
10 OUTPUT 901 ;"DCV3-7"
20 FOR I=1 TO 5
30 ENTER 901 ; A(I)
40 NEXT I
50 END
```

OR

```
10 OUTPUT 901 ;"DCV3-7"
20 P=SPOLL(901)
30 FOR I=1 TO 5
40 ENTER 901 ; A(I)
50 NEXT I
60 END
```

If an error exists, the first program would return the error message instead of the first reading for A(1). In the second program the actual measurement, if it were possible to make the measurement, would be returned to A(1) instead of the error message.

The reading will not be available if;

1. No measurement has been taken.
2. Function FO is asserted and the 3421A is triggered.
3. If the channel list is empty and the 3421A is triggered by T3, DT, or TRIGGER.

If an error occurred during a digital read, the error message is: 888.

**Overload Format.** Three conditions will cause the overload message (+9.99999E+9) to be sent. These are:

1. Voltmeter overload
2. Counter overflowed in TOTalize mode (greater than 65535 counts).
3. REFerence temperature out of range. That is,the REFerence junction temperature is not between 0 and 60 degrees C or the measured thermocouple voltage is not between 0 and 20 mV.

## Simple Programming

We have seen how to send simple commands to the 3421A and how to get measurements from it. Now lets go one step further and look at a simple program. This program takes DC voltage measurements on channels 1, 2, and 3 and

temperature measurements on channels 4 through 9. It is important to notice that the DC voltage readings are read back to the computer (lines 30-50) before the temperature measurements were made. This is because the TEM4-9 command sets up a new channel list and the temperature measurements would over write the DC voltage measurements in the 3421A reading storage.

```
10 ! Sample program
20 OUTPUT 901 ;"DCV1-3"
30 FOR I=1 TO 3
40 ENTER 901 ; B(I)
50 NEXT I
60 OUTPUT 901 ;"TEM4-9"
70 FOR I=4 TO 9
80 ENTER 901 ; B(I)
90 NEXT I
100 FOR I=1 TO 9
110 DISP B(I)
120 NEXT I
130 END
```

## 3421A Interface Capabilities

The following topics, arranged in alphabetical order, deal with HP-IL and HP-IB interface commands and the way the 3421A responds to them. Refer to the I/O programming section of your computer's I/O programming manual for specific information on syntax and actions taken by the interface when sending the message. The examples given apply to the hp- 80 series desktop computers for HP-IL and HP-IB and the -hp- 9845, and 9826 (BASIC) for HP-IB.

# CLEAR

## Example

| HP-IL | | HP-IB |
|---|---|---|
| CLEAR 9 | (device clear) | CLEAR 7 |
| CLEAR 901 | (selected device clear) | CLEAR 709 |

## Comments

Upon receiving the CLEAR message, the 3421A goes through its power-on/reset routine. The power on/reset routine includes:

1. Self Test.
2. Opens all multiplexer and actuator channels.
3. Clears bits of the digital output ports (high impedance state).
4. Voltmeter set to: DC Volts, autorange on, autozero on, 5 ½ digit resolution, internal trigger on.
5. Counter set to 1 second gate time.
6. HP-IL address is not changed.
7. Checks rear panel switches (50/60 Hz, Power-on SRQ, etc.).
8. Channel list set to all available multiplexer channels, addressed sequentially
9. Request Service (SRQ) if self test failed.
10. Reading storage is cleared.

# LOCAL
# LOCAL LOCKOUT
# REMOTE

## Comments

The 3421A does not respond to these commands. This is because the 3421A has no front panel and must be controlled by a computer through an interface. The 3421A is always in remote state.

# REQUIRE SERVICE (SRQ)

## Comments

One important feature of the 3421A is its ability to interrupt the computer when certain conditions occur. Of course the computer must be programmed to respond to the interrupt. The Require Service message (SRQ) is used to implement an interrupt and is independent of all other activity. The 3421A MUST BE PROGRAMMED to request service before the interrupt will take place. Several examples are included in this section to explain interrupt programming.

There are many conditions which can cause an interrupt. The following is a list of those conditions that can cause an interrupt.

1. Power-on/Reset. The 3421A can interrupt the computer when the 3421A power is turned on, receives a Device CLEAR or Selected Device CLEAR, or reset via the rear panel reset switch. The 3421A rear panel switch number 3 must be set to the up position for this interrupt to occur.

2. Data Ready.The 3421A can interrupt the computer after each completed measurement or, if a channel list is measured, the interrupt can occur after all readings are taken. The following commands will set the data read bit: DCV, ACV, TWO, FWO, FRQ, TEM, REF, TOT, RED, BIT, T1, T2, T3, DT, MH, ML, MN, and GET. An example of this, using the DT command, will be shown later in this section.

3. Self Test Error. If any of the seven self tests fail, an interrupt will occur.

4. Event Occurred. The 3421A can monitor the digital input ports and if a specified bit or 8-bit word occurs, it will interrupt the controller. This provides flexibility in timing events. An example of this will be shown later in this section.

5. Low Battery. If the 3421A is being powered by its internal battery, it will generate an interrupt when the battery voltage drops too low. After approximately three minutes, it will open all channels and power down. The following instructions cannot be executed after a low battery is detected: TOT, MH, ML, MN, DT.

6. Abnormal Condition. Abnormal conditions include:

   a. Hardware error
   b. Calibration Error
   c. Command not understood; e.g., the command FR3 is not a legitimate 3421A command
   d. Can't execute the command; e.g., the command DCV25 is sent but channel 25 is a digital channel

e. Self Test failed
f. Low Battery
g. Attempt to load channel list with more than 30 channels
h. Attempt to increment channel list and trigger (T3) but channel list was empty
i. Requested a reading when no data was available
j. Triggered internal voltmeter while function F0 was asserted

## How to use SRQ

When the Require Service message (SRQ) is sent, the computer must first determine which instrument, if more than one is connected to the interface, is requesting service. This is done by conducting a SERIAL POLL (SPOLL) of the devices connected to the interface that are capable of requesting service. When an instrument is serially polled, it responds by sending its "STATUS BYTE" which indicates whether or not it requested service. If it has, bit 6 will be set along with one or more of the other bits to indicate the nature of the request. If the Status Byte for the instrument polled indicates that it was not requesting service, the computer continues to poll the other instruments until the proper one is located. All of these actions assume that the computer has been programmed to respond to the SRQ interrupt as shown in the examples given later.

## Status Register and Status Byte

The Status Register monitors several different 3421A operating conditions and is updated as events occur. If the 3421A SRQ mask is set (set being a "1") for a particular condition and that condition occurs, the 3421A will send an interrupt message to the computer. However, two bits of the 3421A SRQ mask (bit 2 and bit 4) cannot be masked. These two bits correspond to self test error and low battery. If either of these conditions occur, the 3421A will always send the interrupt message. For the remaining conditions, the SRQ mask must be set for the 3421A to send the interrupt message. Anytime the 3421A sends the interrupt message, regardless of whether it is a masked or non-masked condition that caused it to be sent, bit 6 of the Status Register will set. Bit 6 corresponds to "Require Service" and is used by the computer to identify the device that needs attention, assuming the computer is programmed to respond to the interrupt message. The remaining bits can be used by the computer to identify the reason that the interrupt occurred.

The Status Byte is an 8-bit byte that is sent from the 3421A to the computer in response to the SPOLL message. The Status Byte comes from the Status Register and is used to determine the current status of the 3421A.

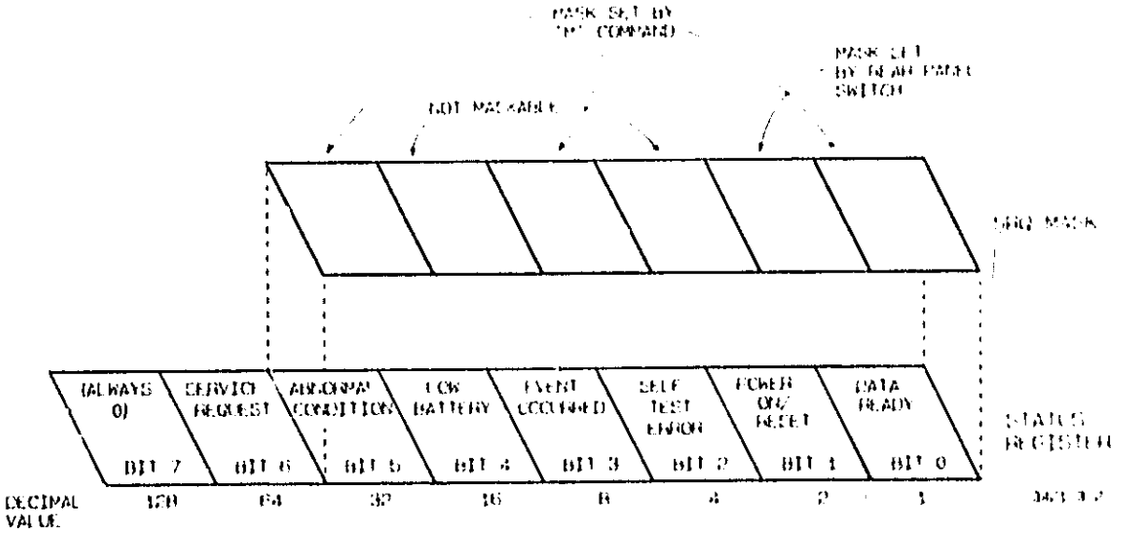
# SRQ (Cont'd)

| Bit 7 N/A (always zero) | Bit 6 Require Service (no mask) | Bit 5 Abnormal Condition (see earlier) | Bit 4 Low Batt. (not maskable) | Bit 3 Event Occurred | Bit 2 Self Test Error (not maskable) | Bit 1 Power on Reset Occurred (switch mask only) | Bit 0 Data Ready |
|---|---|---|---|---|---|---|---|

Status Register

## Setting the SRQ Mask

Think of the SRQ mask as a cover hiding three bits of the Status Register. To "set" the mask you effectively poke holes in the cover. First, determine which conditions you want to interrupt the computer, e.g., data ready, abnormal conditions, etc. Refer to the figure below. Add together the decimal values for the bits that you want to interrupt the controller. Then, output the "M" command followed by the decimal value, that is, "Mx" where x is the decimal value. The following diagram shows the Status Register and the SRQ mask.




To set the SRQ mask for Event Occurred, for example, execute the command: OUTPUT 701;"M8". For either Event Occurred or Data Ready to interrupt the computer, execute: OUTPUT 701;"M9".

# SRQ (Cont'd)

**NOTE**

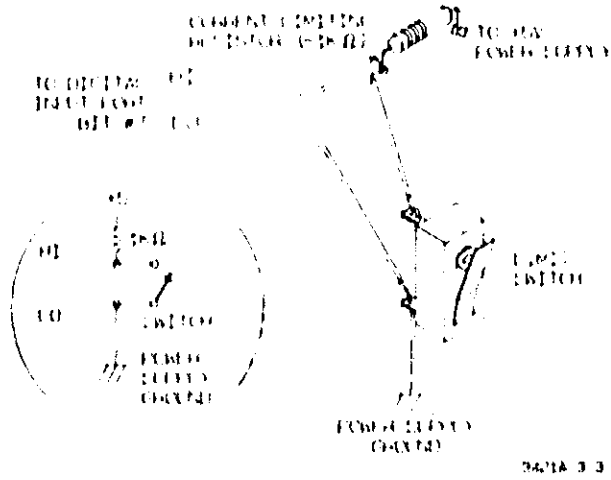
*When you are doing interrupt programming; especially with the digital monitor commands MN, MH, ML, and DT, the end of line sequence should be suppressed. With most -hp- desktop computers this is done with the OUTPUT USING "#,K" command. The last character in the command string must be either a colon (:), a semicolon (;), a carriage return, or a linefeed. The following program examples show how this is done.*

*If you are using the 3421A with its HP-IB interface, the 3421A must be placed in an 'UNLISTEN' mode before it can interrupt the controller. With most -hp- desktop computers, this is done with the SEND 7,UNL command. These lines are shown in the following examples and may be deleted if you are using the HP-IL interface.*

## Example 1. Event Occurred

This is a simple example that demonstrates the usefulness of the SRQ interrupt. In this example, we will use Event Occurred to monitor one bit, bit 17, of a 44465A Digital I/O assembly. When that bit goes low, the 3421A will signal the computer that the event has occurred. Event occurred, as in this example, might be used to monitor limit or position switches.

The associated illustration shows the external connections that will need to be made. Remember that the Digital I/O assembly must be in slot 1 for the program to work. Type in the program and run it. After the computer displays "READY", close the switch. Notice that the program jumps down to the interrupt subroutine.



# SRQ (Cont'd)

HP-IL Example

```
10 ! Event occurred example
20 ! HP- 85 version
30 ! 3421A at address 901
40 CLEAR
50 CLEAR 9
60 OUTPUT 901  "M8,ML17"
70 ON INTR 9 GOSUB 1000
80 ENABLE INTR 9;8
90 DISP "READY"
100 ! Main program goes here
980 GOTO 100
990 END
1000 ! Serial poll subroutine
1010 P=SPOLL(901)
1020 STATUS 9,1 ; A
1030 IF P=73 THEN DISP "EVENT OC
        CURRED"
1040 RETURN
```

| Line | Description |
|---|---|
| 40 | Clears the display. |
| 50 | Clears the Status Register. |
| 60 | Sets the 3421A for SRQ when event occurs (M8) and for monitor when bit 17 goes low (ML17). |
| 70 | This line tells the computer where to go when the interrupt occurs (line 1000). |
| 80 | ENABLE INTR 9;8 enables the computer to respond to the interrupt. |
| 100-990 | The main body of the program goes here. Line 980 will keep the main programming running indefinitely. |
| 1000 | This is the start of the interrupt subroutine. |
| 1010 | SPOLL returns the value of the Status Register (the Status Byte) to variable P. It also resets bit 6 of the Status Register. |
| 1030 | P is tested to determine what caused the interrupt. Bit 6 of the Status Register should be set since an interrupt occurred. This bit has a value of 64. Bit 3 should also be set for Event Occurred. This bit has a value of 8. Also, bit 0 will be set. Combined, these bits have a value of 73. |
| 1040 | End of subroutine. |

# SRQ (Cont'd)

HP-IB Example

```
 10 ! Event occurred example
 20 ! -HP- 85 version
 30 ! 3421A at address 709
 40 CLEAR
 50 CLEAR 7 @ WAIT 5000
 60 OUTPUT 709 ;"M8;ML17"
 70 SEND 7 ; UNL
 80 ON INTR 7 GOSUB 1000
 90 ENABLE INTR 7;8
100 DISP "READY"
110 ! Main program goes here
980 GOTO 110
990 END
1000 ! Serial Poll subroutine
1010 P=SPOLL(709)
1020 STATUS 7,1 ; A
1030 IF P=73 THEN DISP "EVENT OC
        CURRED"
1040 RETURN
```

| Line | Description |
|---|---|
| 40 | Clears the display. |
| 50 | Clears the Status Register; wait 5 seconds or system error results. |
| 60 | Sets the 3421A for SRQ when event occurs (M8) and for monitor when bit 17 goes low (ML17). |
| 70 | The UNL (ten command permits the 3421A to interrupt the computer. Note, this line is not necessary if you are using HP-IL. |
| 80 | This line tells the computer where to go when the interrupt occurs (line 1000). |
| 90 | ENABLE INTR 7;8 enables the computer to respond to the interrupt. |
| 110-990 | The main body of the program goes here. Line 980 will keep the main programming running indefinitely. |
| 1000 | This is the start of the interrupt subroutine. |
| 1010 | SPOLL returns the value of the Status Register (the Status Byte) to variable P. It also resets bit 6 of the Status Register. |
| 1030 | P is tested to determine what caused the interrupt. Bit 6 of the Status Register should be set since an interrupt occurred. This bit has a value of 64. Bit 3 should also be set for Event Occurred. This bit has a value of 8. Also, bit 0 will be set. Combined, these bits have a value of 73. |
| 1040 | End of subroutine. |

# SRQ (Cont'd)

## Example 2. Abnormal Condition

There are several conditions which can cause bit 5 (abnormal condition) in State Register 1 (Status Register) to set. If any bit in State Registers 2, 3, or 4 is set, then bit 5 of the Status Register is set. The abnormal condition bit is also set if bit 2 or bit 4 of the Status Register is set. Abnormal conditions include:

1. Hardware Error
2. Calibration Error
3. Command not understood; e.g., the command FR3 is not a legitimate 3421A command
4. Can't execute the command; e.g., the command DCV25 is sent but channel 25 is a digital channel
5. Self Test failed
6. Low Battery
7. Attempt to load channel list with more than 30 channels
8. Attempt to increment channel list and trigger (T3) but channel list was empty
9. Requested a reading when no data was available
10. Triggered internal voltmeter while function F0 was asserted

The question arises then as to which one actually caused the interrupt. The following example shows a program which will allow you to determine the exact nature of the "Abnormal Condition." The program makes use of the SR command. This command sends 24 bytes which can tell you the exact status of the 3421A. However, we are only interested in the first 4 bytes as they contain the error information. The remaining 20 bytes are described in the blue pages at the end of this chapter.

# SRQ (Cont'd)

```
10 ! Abnormal condition example
20 ! -hp- 85 version
30 ! 3421A at address 901
40 OUTPUT 901 ;"M32"
50 ON INTR 9 GOSUB 1000
60 ENABLE INTR 9;8
70 OUTPUT 901 ;"DCV"
80 GOTO 80
90 END
1000 OUTPUT 901 ;"SR"
1010 ENTER 901 ; A,B,C,D
1020 DISP "STATUS REGISTER VALUE: ";A
1030 DISP "ERROR BYTE VALUE: ";B
1040 DISP "HARDWARE ERROR BYTE: ";C
1050 DISP "CALIBRATION ERROR VALUE: ";D
1060 RETURN
```

| Line | Description |
|---|---|
| 40 | This line outputs the SRQ mask for abnormal condition. |
| 50 | Line 50 is used to tell the computer where to go when an interrupt occurs (line 1000). |
| 60 | ENABLE INTR 9;8 enables the computer to respond to interrupts. |
| 70 | DCV is a legitimate 3421A command. Therefore there will be no interrupt. Replace this command with FR3 and rerun the program. |
| 80-90 | The body of the program goes here. |
| 1000 | This is the first line of the interrupt subprogram. The "SR" command is used to tell the 3421A to send it status information. |
| 1010 | The values of the first 4 registers are entered into the computer and stored into variables A, B, C, D. |
| 1020-1050 | The values for the registers are displayed along with the register name. |
| 1060 | This line causes the program control to return to where it was interrupted. |

Line 70 in the program contains the command "DCV". This is a legitimate 3421A command. Therefore, since there is no abnormal condition the interrupt will not occur. Now replace the DCV command with the command "FR3" and rerun the program. FR is not a legitimate command so an abnormal condition will exist. However, the 3421A will assume the R3 range. Compare the 4 values returned by the program to the charts below. Remember that the value returned is the sum of the values of the individual bits that are set.

## Example 3. Advanced SRQ Interrupt Programming Using The Digital Trigger Command

Data Ready is a feature of the 3421A that allows it to interrupt the controller after each completed measurement or, when used with a channel list, each group of measurements. Typically, the Data Ready feature is used only with the Digital Trigger command while utilizing SRQ interrupts. Digital Triggering allows the voltmeter to begin taking readings when a digital input goes low. A digital input is considered to go low when no current is passing through the digital port.

Abnormal conditions were previously explained under example 2.

To enable the Data Ready and Abnormal Condition features on the 3421A, you must set bit 0 and bit 5 in the SRQ mask. Remember that bit 0 in the status register will be true (a "1") anytime data is ready and that bit 5 will be true anytime there is an abnormal condition. However, neither condition will cause the 3421A to interrupt the computer unless the SRQ mask is set accordingly. The pattern for the SRQ mask for these conditions would look like:

| Bit #: | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Value: | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | sum | 33 |

Therefore, use the command "M33" to set the SRQ mask for data ready and abnormal condition.

Now, whenever the 3421A has completed its measurement task it will interrupt the computer via the SRQ data ready interrupt. Likewise, it will interrupt the computer whenever there is an abnormal condition. Looking at this from another perspective, the computer will only be interrupted if bit 0 or bit 5 (or an unmaskable bit) in the Status Register is true. Bits 1 and 3 cannot cause the interrupt because the mask was not set for those bits.

The following programming example demonstrates the handling of Data Ready, Abnormal Condition, and all non-maskable interrupts. This programming example, as with most SRQ programming, requires a knowledge of advanced programming practices. This program exhibits many of the considerations necessary when creating interrupt driven programs, including:

Digital Trigger initiation of channel list measurements;
detecting and displaying all interrupt conditions;
and for abnormal (error) conditions, interrogates the
3421A to find out why the error occurred.

# SRQ (Cont'd)

It is recommended that the basic framework of this program be used when performing advanced interrupt programming. It will be necessary, however, to modify the main body, the latter part of subroutine #1 and all of subroutine #3 to meet the specific application.

```
10  !
20  ! ==========================
30  ! HP3421A SRQ interrupt dri-
40  ! ven channel list measure-
50  ! ment programming example
60  ! ==========================
70  !
80  DIM A(30),M(1),L(1)
90  L=7 ! 85 HPIB INTERFACE SELE
    CT CODE
100 M=701 ! HP3421A HPIB ADDRESS
110 CLEAR ! SCREEN
120 !
130 ! ==========================
140 ! Initialize entire system
150 ! for an interrupt program
160 ! ==========================
170 !
180 STATUS L,1 ; S ! ASSURES SRQ
     RECEIVED FLAG IS CLEARED IN
     85
190 ON INTR L GOSUB 580 ! INTERR
    UPT HANDLING SUBROUTINE
200 ENABLE INTR L;8 ! GET READY
    TO RECEIVE SRQ INTERRUPTS FR
    OM HP3421A
210 CLEAR L ! RESET HPIB INSTRUM
    ENTS
220 WAIT 5000 ! ALLOW TIME FOR I
    NSTUMENTS TO RESET
230 OUTPUT M ;"F0T0" ! DISABLE 3
    421A POWER UP FUNCTIONS AND
240 ! AUTO TRIGGER SO DATA IS NO
    T ALWAYS READY
250 ! UPON ENABLING OF DATA READ
    Y INTERRUPT (COMMAND M1 OR M
    33)
260 S=SPOLL(M) ! ASSURE THE CLEA
    RING OF ALL STATUS BITS IN 3
    421A (ESPECIALLY DATA READY
    BIT)
270 !
280 ! ==========================
290 ! Main program body
300 ! ==========================
310 !
320 ! THE FOLLOWING LINES HAVE B
    EEN INTENTIONALLY COMMENTED
    OUT
330 ! THEIR EQUIVALENT FUNCTION
    CAN BE SENT AS ONE COMMAND A
    S INLINE 460
340 ! OUTPUT M ;"T0" ! ENBL CH L
    ST, DATA STORAGE, WAIT FOR T
    2 OR T3 TRIGGER
350 ! OUTPUT M ;"FIR1" ! TAKE DC
    V MEASUREMENTS IN 30V RANGE
360 ! OUTPUT M ;"Z0" ! DO NOT US
    E AUTO ZERO (FASTER CHANNEL
    LIST SEQUENCING)
370 ! OUTPUT M ;"N4" ! 4.5 DIGIT
     MEASUREMENTS
380 ! OUTPUT M ;"LS13-19,13-19,1
    3-19,13-19,13,14" ! LOAD SIN
    GLE CHANNEL CLOSURE LIST WIT
    H
390 ! THIS SEQUENCE
400 ! OUTPUT M ;"M33" ! INTERRUP
    T 85 WHEN MEASUREMENTS COMPL
    ETED (DATA READY) OR UPON
410 ! ABNORMAL CONDITION (ERROR)
420 ! OUTPUT M ;"DT7" ! INITIATE
     A T3 TRIGGER WHEN DIGITAL P
    ORT GOES LOW (IE. HIGH NOT C
    ONNECTED
430 ! TO 5V, LOW NOT CONNECTED T
    O GROUND OR THE TWO SHORTED,
440 ! (IE. NO CURRENT THROUGH PO
    RT)
450 ! THE PREVIOUSE COMMAND SEQU
    ENCE MAY BE SENT ALL AT ONCE
     AS IN
460 OUTPUT M ;"T0F1R12N4LS13-19
    ,13-19,13-19,13-19,13,14;M33
    ;DT7"
470 N=30 ! SET READ-BACK COUNTER
     EQUAL TO NUMBER OF CHANNELS
     LOADED INTO CHAN LIST ABOVE
480 SEND L ; UNL ! NECESSARY OR
    HP3421A WILL NOT INTERRUPT T
    HE 85
490 F=0 ! PROGRAM FLAG INDICATIN
    G THAT THE 3421A IS ALL SET
    FOR MEASUREMENT TRIGGER
500 DISP "READY"
510 CLEAR ! SCREEN
520 IF F=1 THEN GOTO 460 ! SET U
    P FOR NEW TRIGGER OF MEASURE
    MENTS490
530 GOTO 500 ! CAUSE READY TO BL
    INK UNTIL INTERRUPT IS RECEI
    VED (DIGITAL TRIG RCVD)
540 END
550 !
560 ! ==========================
570 !        SUBROUTINE #1
580 ! Interupt subroutine to
590 ! print type of interrupt
600 ! received and if data
610 ! ready read the stored
620 ! values from the HP3421A
630 ! internal buffer
640 ! ==========================
```

# SRQ (Cont'd)

```
650 !
660 STATUS L,1 ; S ! CLEARS SRQ
     RECEIVED FLAG IN 85
670 DISP " "
680 DISP "INTERRUPT RECEIVED"
690 DISP "=================="
700 S=SPOLL(M) ! POLL (QUERY) IN
    STRUMENT TO DETERMINE REASON
     FOR SRQ
710 IF BIT(S,6)=1 THEN DISP "SRQ
     INTERRUPT"
720 IF BIT(S,0)=1 THEN DISP "DAT
    A READY"
730 IF BIT(S,1)=1 THEN DISP "POW
    ER ON RESET"
740 IF BIT(S,2)=1 THEN DISP "SEL
    F TEST ERROR"
750 IF BIT(S,3)=1 THEN DISP "EVE
    NT OCCURRED"
760 IF BIT(S,4)=1 THEN DISP "LOW
     BATTERY"
770 IF NOT BIT(S,5)=1 THEN GOTO
    800
780 DISP "ABNORMAL CONDITION"
790 GOSUB 920
800 DISP "=================="
810 WAIT 2000 ! ALLOW USER TIME
    TO VIEW ERROR
820 F=1 ! TELL PROGRAM ABOVE NOT
     TO CONTINUE TO LOOP
830 ! BUT RATHER TO GO UP AND SE
    T UP FOR NEW TRIGGER FIRST
840 ENABLE INTR L;8 ! MUST REENA
    BLE SRQ INTERRUPT
850 IF BIT(S,1)=1 THEN GOTO 910
    ! POWER ON RESET (ALSO CAUSE
    S DATA READY BIT TO BE SET D
    UE
860 ! TO DEFAULT AUTO TRIG  OCV
    STATE OF HP3421A, IN THIS MO
    DE DATA IS ALWAYS READY!)
870 IF BIT(S,2)=1 THEN GOTO 910
    ! SELF TEST ERROR
880 ! (DID A PWR-ON OR DEVICE CL
    EAR WHICH ALSO CAUSES DATA R
    EADY BIT TO BE SET DUE
890 ! TO DEFAULT AUTO TRIG, OCV
    STATE OF HP3421A, IN THIS MO
    DE DATA IS ALWAYS READY!)
900 IF BIT(S,0)=1 THEN GOSUB 121
    0 ! VALID DATA IS READY, REA
    D IT
910 RETURN
920 !
930 ! ==========================
940 !        SUBROUTINE #2
950 ! Subroutine for reading
960 ! error type from HP3421A
970 ! and displaying
980 ! ==========================
990 !
1000 OUTPUT M ;"SR" ! QUERY INST
     RUMENT TO DETERM WHAT ERROR
      IS
1010 ENTER M ; S1,S2,S3 ! GET 2N
     D AND 3RD STATUS REGISTERS
     TO DETERMINE ERROR
1020 FOR K=4 TO 24
1030 ENTER M ; S0 ! EXTRA READS
     OF OTHER STATUS BYTES (ALSO
      CLEARS INDICATOR ON HP3421
     A DISPLAY)
1040 NEXT K
1050 IF BIT(S2,0)=1 THEN DISP "
      TRIGGERED IN F0 MODE"
1060 IF BIT(S2,1)=1 THEN DISP "
      REQUESTED DATA UNAVAILABLE
     "
1070 IF BIT(S2,2)=1 THEN DISP "
      INVALID SYNTAX"
1080 IF BIT(S2,3)=1 THEN DISP "
      INVALID OPTION LOCATION"
1090 IF BIT(S2,4)=1 THEN DISP "
      BATT LOW, NO TOT,MH,ML,MN,
     OT"
1100 IF BIT(S2,5)=1 THEN DISP "
      T3 TRIG WHEN CHAN LIST EMP
     TY"
1110 IF BIT(S2,6)=1 THEN DISP "
      EXCEEDED CHAN LIST LIMIT O
     F 30"
1120 IF BIT(S3,0)=1 THEN DISP "
      INVALID CAL RAM CHECK SUM"
1130 IF BIT(S3,1)=1 THEN DISP "
      INVALID ROM 1 CHECKSUM"
1140 IF BIT(S3,2)=1 THEN DISP "
      INVALID ROM 0 CHECKSUM"
1150 IF BIT(S3,3)=1 THEN DISP "
      A/D FAILED SLOPE TEST"
1160 IF BIT(S3,4)=1 THEN DISP "
      PROCESSOR RAM FAILED TEST"
1170 IF BIT(S3,5)=1 THEN DISP "
      RAM U504 FAILED TEST"
1180 IF BIT(S3,6)=1 THEN DISP "
      RAM U503 FAILED TEST"
1190 IF BIT(S3,7)=1 THEN DISP "
      10M, 100:1 DIVIDER TEST FA
     ILED"
1200 RETURN
1210 !
1220 ! ==========================
1230 !        SUBROUTINE #3
1240 ! Subroutine for reading
1250 ! measurement values from
1260 ! the HP3421A.
1270 ! ==========================
1280 !
1290 CLEAR ! SCREEN
1300 DISP "READING MEASUREMENTS"
1310 PRINT "  HP-3421A MEASUREME
     NTS"
1320 PRINT "==================
     ======"
1330 FOR I=1 TO N STEP 1
1340 ENTER M ; A(I)
1350 PRINT "MEASUREMENT #";I;" =
     ";A(I)
1360 NEXT I
1370 FOR H=1 TO 5
1380 PRINT ! FORM FEED
1390 NEXT H
1400 RETURN
```

# SRQ (Cont'd)

The four registers will be cleared after all four have been read by the ENTER command. The following chart shows the meaning of each bit in the registers and its value. Remember that the decimal value returned is the sum of the values of the individual bits that are set within that register. There are actually 24 registers that can be read with the SR command, the remaining 20 are 3421A status registers. These can be used to report what option assemblies are available in the 3421A, which channels are closed, the setting of the SRQ, XOR, and AND masks, etc. Refer to the blue pages at the end of this chapter.

| Register | Bit Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 1 Status Register | Always 0 | SRQ | Abnormal Condition | Low Battery | Event Occurred | Self Test Error | Power on Reset | Data Ready |
| 2 Error Register | Undefined. May be 1 or 0 | Tried to load channel list with more than 30 channels | Channel list is empty but tried to execute a 13 | Battery is low but tried to do TOT,MN, MH, ML | Wrong type of option for command | Invalid Syntax | No Data ready but Addressed to talk. | Func FO asserted but triggered |
| 3 Hardware Error | 10 MB test error | RAM Error | RAM Error | μP RAM Error | A/D Error | ROM 0 Error | ROM 1 Error | Cal. RAM Checksum Error |
| 4 Cal Error | Undefined. may be 1 or 0 | A/D Error | CAL RAM Bad | CAL attempted but not enabled | Invalid CAL Zero | Invalid CAL Signal | Invalid CAL Number | Invalid CAL Function or Range |
| Bit Value | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

# CHAPTER 3 CON'T

# SPOLL
# (Serial POLL)

## Example

| HP-IL | HP-IB | |
|---|---|---|
| ▫ = SPOLL (901) | P = SPOLL (709) | (-hp- 85,9826A) |
| | STATUS 709;P | (-hp- 9835,9845A/B) |

## Comments

Serial Poll allows you to determine the current status of the 3421A even if no SRQ mask has been established. When the 3421A receives the Serial Poll message, it returns its Status Byte (from the Status Register). The value returned is the sum of the individual bits that are set. For example, if bits 6 and 1 are set the value would be 66 (64 + 2 = 66). The 8 bits of the Status Byte and their respective values are shown in the following figure. All of these bits were described in the previous section, Require Service.

| | Bit 7 N/A Always 0 | Bit 6 SRQ | Bit 5 Abnormal Condition | Bit 4 Low Battery | Bit 3 Event Occurred | Bit 2 Self Test Error | Bit 1 Power on Reset | Bit 0 Data Ready |
|---|---|---|---|---|---|---|---|---|
| Decimal Value | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

Status Byte (Register)

Reading the status byte clears all bits except for the data ready bit (bit 0) and the low battery bit (bit 4). The low battery bit is cleared only by cycling the front panel on/off switch when the battery has been recharged. The data ready bit is cleared when the reading is read or no longer available.

All Status Register bits are reset by a Device Clear message. Bits 1, 2, 3, and 5 are cleared by a SPOLL if bit 6 was set. If bit 6 was a 0, indicating that the 3421A was not generating the interrupt, no bits are changed. Bit 4 is cleared only by turning the line switch off and back on again. Bit 1 is cleared by entering the current reading to the computer.

# TRIGGER

## Example

| HP-IL | HP-IB |
|---|---|
| TRIGGER 9 | TRIGGER 7 |
| TRIGGER 901 | TRIGGER 709 |

## Comments

If the 3421A is an addressed listener, the TRIGGER statement will cause the voltmeter to take one or more readings. For example, if scan trigger (T3) or hold/enable scan trigger (T0) is asserted, the TRIGGER command will initiate measurements sequentially from the channel list.

If internal trigger T1 is asserted, no measurements will be taken by the voltmeter until either the TRIGGER command is executed, a reading is asked for (i.e., ENTER901;A) or T2 is asserted.

The software trigger T2 will cause one reading to be taken. Subsequent readings can be initiated by either TRIGGER or sending T2.

Neither T1 or T2 will open or close a channel before taking the reading.

## Topics In Advance Programming

The following two programs illustrate the flexibility and measurement power of the 3421A. The programs include temperature measurements using either thermistors or thermocouples. Although the programs were developed on an -hp- 85 desktop computer with an HP-IL interface, they can easily be modified to run on other computers. In some cases, suggestions are made for modifying the programs to suit your individual needs.

# TEMPERATURE MEASUREMENTS

## Thermistor

This first program computes the temperature, in °C, corresponding to the resistance of a thermistor. The program is designed to work with thermistors exhibiting a resistance of 5.000 kOhms at 25 °C, such as a type 44007 (-hp- part number 0837-0164) or equivalent.

The program gives you the option of selecting either 2- or 4-wire ohms measurements to be made on the thermistor. As it stands, the program sets the 3421A for a 2-wire measurement. This will give suitable results if the thermistor is used at a temperature where its resistance is much greater than the resistance of the connecting leads. For greatest accuracy from a thermistor, a 4-wire measurement should be used. To convert the program to a 4-wire measurement, delete the exclamation mark from line 80 and make line 70 a comment statement.

The program will prompt for a channel number (lines 60 and 70), type in one channel number and press [END LINE]. The program will continually make measurements on that one channel, convert the reading to °C and display the temperature.

```
10 ! Temperature measurements
20 ! with a type 44007 thermistor
30 ! -HP- 85 version
40 ! 34210 at address 901
50 DISP "CHANNEL NUMBER?"
60 INPUT C
70 OUTPUT 901 ;"TWO";C
80 ! OUTPUT901;"FWO";C
90 Q3=.0000000941
100 Q2=.00023595
110 Q1=.001286
120 ENTER 901 ; B
130 Q4=LOG(B)
140 P=1/(Q1+Q4*(Q2+Q4*Q4*Q3))-273.15
150 DISP P
160 GOTO 70
170 END
```

| Lines | Description |
|---|---|
| 50-60 | These two lines get the channel number. |
| 70-80 | Line 70 sets the 3421A up for a 2-wire resistance measurement on the thermistor. Line 80 can be used for 4 wire resistance measurements. |
| 90-110 | These three lines contain the conversion coefficients for the 44007 thermistor. |
| 120 | Line 120 enters the measured resistance from the 3421A. |
| 130-140 | These two lines convert the measured resistance to the corresponding temperature. |
| 150 | The calculated temperature is displayed. |
| 160 | The GOTO70 statement returns the program to line 70 for another measurement. |

# TEMPERATURE MEASUREMENTS (Cont'd)

## Thermocouple

The TEM command can be used for temperature measurements as long as you use T-type thermocouples. But what if you want to use other types of thermocouples? This next program example demonstrates the procedure for making thermocouple temperature measurements. Although the program was written specifically for J-type thermocouples, it can easily be adapted for other types simply by changing the conversion coefficients. A chart is provided listing the coefficients for several thermocouples. In this example program, the J-type thermocouple is connected to channel 17.

There are five steps that must be performed in making accurate temperature measurements from thermocouples. The following explanation of these steps are referenced to line numbers in the program.

1. Lines 190 and 200. Measure the temperature of the 44462A assembly terminal block. This is done with the REF command and is known as the REFerence Temperature. The Reference Temperature is used to effect icepoint compensation of the thermocouple measurement.

2. Line 210. Convert the Reference Temperature to a thermocouple reference voltage. The coefficients used in this step are determined by the type of thermocouple being compensated. The equation used is: $V = R0 + (Tref * R1) + (Tref^2 * R2)$. In this equation, Tref is the Reference temperature and R0, R1, and R2 are the conversion coefficients. Later in this section, a chart is provided listing the coefficients for various thermocouples.

3. Lines 230 and 240. Measure the thermocouple voltage.

4. Line 250. Add the Reference voltage to the measured thermocouple voltage.

5. Line 260. Convert the sum voltage (step 4) to its corressponding temperature (Degrees C). Line 270 is used to round the computed temperature to 2 decimal places. The equation used in line 260 is:

$$Temperature = P0 + (V * P1) + V^2 * P2) + (V^3 * P3) + (V^4 * P4) + \ldots + (V^9 * P9)$$

In this equaton, V is the voltage computed in step 4. The coefficients P0 through P9 are listed in the chart for various thermocouples.

# TEMPERATURE MEASUREMENTS (Cont'd)

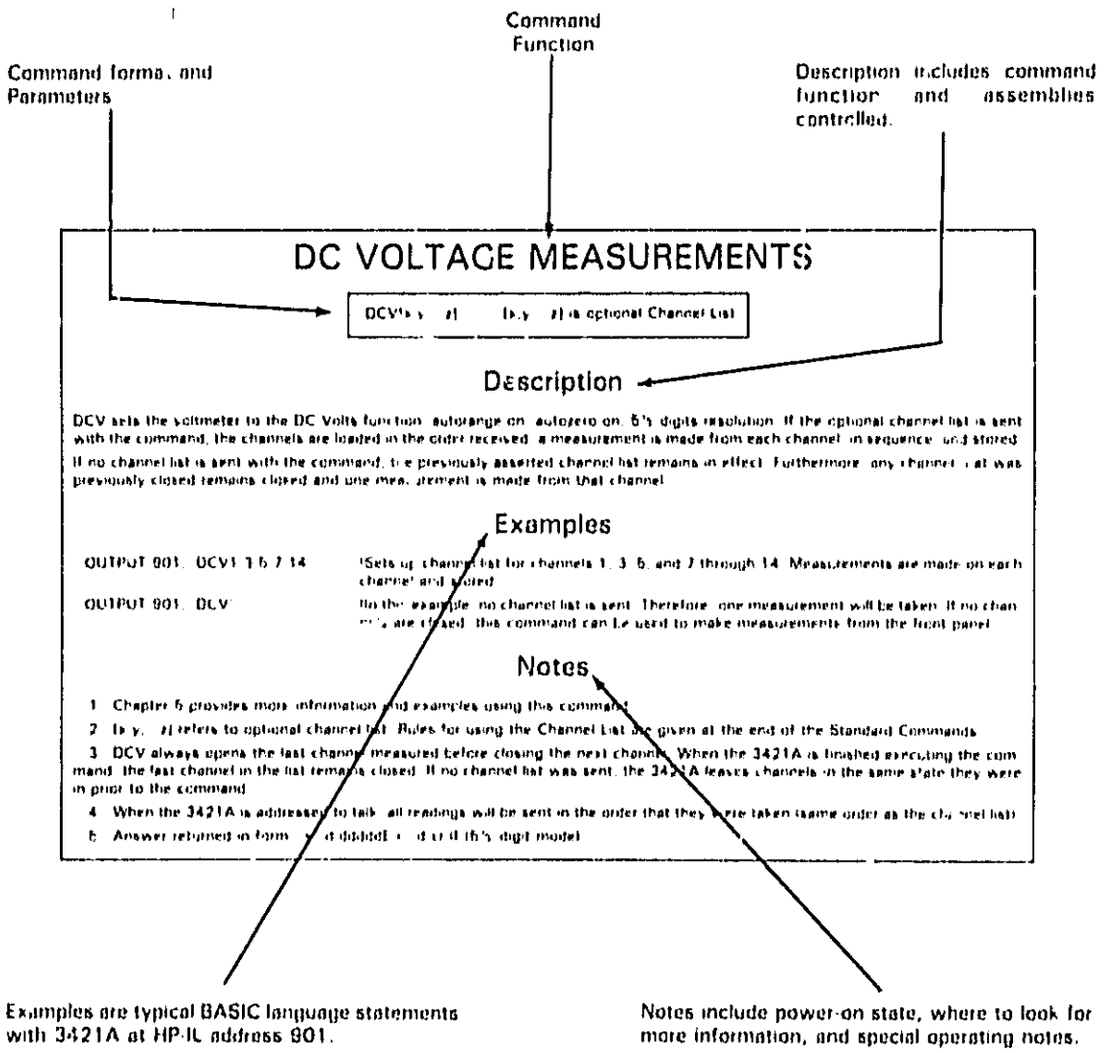
```
10 ! J-type thermocouple program
20 ! -HP- 85 version
30 ! 3421A at address 901
40 ! conversion coefficients
50 R0=-.00000075
60 R1=.00005053
70 R2=.000000023
80 P0=-.36
90 P1=19750.9
100 P2=-175117
110 P3=1.821297E7
120 P4=-2831128000
130 P5=271508380000
140 P6=-1.38014121E13
150 P7=3.79243843E14
160 P8=-5.3719255E15
170 P9=3.0840254E16
180 ! Measure and convert reference
190 OUTPUT 901 ;"REF17"
200 ENTER 901 ; R
210 V1=R0+R*(R1+R*R2)
220 ! Measure and convert thermocouple voltage
230 OUTPUT 901 ;"DCV17"
240 ENTER 901 ; V
250 V=V+V1
260 T1=P0+V*(P1+V*(P2+V*(P3+V*(P4+V*(P5+V*(P6+V*(P7+V*(P8+V*P9)))))))))
270 T=INT(T1*100+.5)/100
280 DISP "TEMPERATURE = ";T
290 GOTO 190
300 END
```

Thermocouple Type

| Line Number | J | E | R | K | S |
|---|---|---|---|---|---|
| 50 | 7.5E 7 | 1.2E 7 | 2.1E 7 | 8.2E 7 | 2.0E 7 |
| 60 | 6.053E 5 | 5.866E 5 | 6.334E 6 | 3.964E 5 | 5.442E 6 |
| 70 | 2.3E 8 | 4.6E 8 | 1.2E 8 | 1.6E 8 | 1.1E 8 |
| 80 | 3.6E 1 | 2.1E 1 | 1.6E0 | 5.1E 2 | 1.4E0 |
| 90 | 1.97509E4 | 1.61299E4 | 1.726466E5 | 2.48503E4 | 1.73646E5 |
| 100 | 1.75117E5 | 2.05411E5 | 3.27669E7 | 3.82662E5 | 3.26267E7 |
| 110 | 1.821297E7 | 3.049432E7 | 7.787787E9 | 9.9661067E7 | 8.477336E9 |
| 120 | 2.831128E9 | 2.9690242E9 | 1.13982593E12 | 1.0820624E1C | 1.327040E12 |
| 130 | 2.7150838E11 | 1.4284968E11 | 1.01396299E14 | 6.0392866E11 | 1.2361123E14 |
| 140 | 1.38014121E13 | 3.7221944E12 | 5.4842602E15 | 1.9109E13 | 6.79267949E15 |
| 150 | 3.79243843E14 | 5.3981272E13 | 1.7414496E17 | 3.4782347E14 | 2.0689294E17 |
| 160 | 5.3719266E15 | 4.1056296E14 | 2.9236606E18 | 3.3991028E15 | 2.8874849E18 |
| 170 | 3.0840264E16 | 1.2777466E15 | 1.9280744E19 | 1.3828614E16 | 8.2663728E18 |

# COMMAND DIRECTORY

This command table for the 3421A is divided into two groups, first the Standard Commands and second the Advanced Commands. The Standard Commands are arranged by command group: VOLTMETER, TEMPERATURE, COUNTER, DIGITAL, and CHANNEL. Refer to chapters 5 and 6 in this manual for more information on channel addressing, etc. The Advanced Commands are also arranged by function: A/D (voltmeter, counter), DIGITAL, CHANNEL, and INSTRUMENT. The following format is used to describe the commands.



# DC VOLTAGE MEASUREMENTS

DCV[x,y,...z] [x,y,...z] is optional Channel List

## Description

DCV sets the voltmeter to the DC Volts function, autorange on, autozero on, 5½ digits resolution. If the optional channel list is sent with the command, the channels are loaded in the order received, a measurement is made from each channel, in sequence, and stored.

If no channel list is sent with the command, the previously asserted channel list remains in effect. Furthermore, any channel that was previously closed remains closed and one measurement is made from that channel.

## Examples

| | |
|---|---|
| OUTPUT 901;"DCV1,3,5,7 14" | !Sets up channel list for channels 1, 3, 5, and 7 through 14. Measurements are made on each channel and stored. |
| OUTPUT 901;"DCV" | !In this example, no channel list is sent. Therefore, one measurement will be taken. If no channels are closed, this command can be used to make measurements from the front panel. |

## Notes

1. Chapter 5 provides more information and examples using this command.
2. [x,y,...z] refers to optional channel list. Rules for using the Channel List are given at the end of the Standard Commands.
3. DCV always opens the last channel measured before closing the next channel. When the 3421A is finished executing the command, the last channel in the list remains closed. If no channel list was sent, the 3421A leaves channels in the same state they were in prior to the command.
4. When the 3421A is addressed to talk, all readings will be sent in the order that they were taken (same order as the channel list).
5. Answer returned in form: +/-d.ddddddE+-d cr lf (6½ digit model).
6. If no parameters are sent, then T2 (software single trigger) is executed. If parameters are sent, then T3 is executed.

# AC VOLTAGE MEASUREMENTS

ACV[x,y,...z] [x,y,...z] is optional channel list.

## Description

ACV sets the voltmeter to the AC Volts function, autorange on, autozero on, 4½ digits resolution. If the optional channel list is sent with the command, the channels are loaded in the order received, a measurement is made from each channel, in sequence, and stored.

If no channel list is sent with the command, the previously asserted channel list remains in effect. Furthermore, any channel that was previously closed remains closed and one measurement is made from that channel.

## Examples

| | |
|---|---|
| OUTPUT 901;"ACV5,1 3,21,22" | !Sets up channel list as: 5, 1, 2, 3, 21, and 22. Measurements are made on each channel and stored. |
| OUTPUT 901;"ACV" | !In this example, no channel list is sent. Therefore, one measurement will be taken. If no channels are closed, this command can be used to make measurements from the front panel. |

## Notes

1. Chapter 5 provides more information and examples using this command.
2. [x,y,...z] refers to optional channel list. Rules for using the Channel List are given at the end of the Standard Commands.
3. ACV always opens the last channel measured before closing the next channel. When the 3421A is finished executing the command, the last channel in the list remains closed. If no channel list was sent, the 3421A leaves channels in the same state they were in prior to the command.
4. When the 3421A is addressed to talk, all readings will be sent in the order that they were taken (same order as the channel list).
5. Answer returned in form: +/-d.ddddddE+-d cr lf.
6. If no parameters are sent, then T2 (software single trigger) is executed. If parameters are sent, then T3 is executed.

# 2-WIRE RESISTANCE MEASUREMENTS

TWO[x,y,...z] [x,y,...z] is optional channel list.

## Description

TWO sets the voltmeter to the 2 wire resistance function, autorange on, autozero on, 5½ digits resolution. If the optional channel list is sent with the command, the channels are loaded in the order received, a measurement is made from each channel, in sequence, and stored. Refer to T3 in Advanced Commands.

If no channel list is sent with the command, the previously asserted channel list remains in effect. Furthermore, any channel that was previously closed remains closed and one measurement is made from that channel. Refer to T2 in the Advanced commands.

## Examples

| | |
|---|---|
| OUTPUT 301;"TWO1,3,5,7 14" | !Sets up channel list for channels 1, 3, 5, and 7 through 14. Measurements are made on each channel and stored. |
| OUTPUT 901;"TWO" | !In this example, no channel list is sent. Therefore, one measurement will be taken. If no channels are closed, this command can be used to make measurements from the front panel. |

## Notes

1. Refer to Chapter 5 for more information and examples.
2. [x,y,...z] refers to optional channel list. Rules for using the Channel List are given at the end of the Standard Commands.
3. TWO always opens the last channel measured before closing the next channel. When the 3421A is finished executing the command, the last channel in the list remains closed. If no channel list was sent, the 3421A leaves channels in the same state they were in prior to the command.
4. When the 3421A is addressed to talk, all readings will be sent in the order that they were taken (same order as the channel list).
5. Answer returned in form: +/-d.ddddddE+/-d cr lf
6. If no parameters are sent, then T2 (software single trigger) is executed. If parameters are sent, then T3 is executed.

# 4-WIRE RESISTANCE MEASUREMENTS

FWO[x,y,...z] [x,y,...z] is optional channel list.

## Description

FWO sets the voltmeter to the 4 wire resistance function, autorange on, autozero on, 5½ digits resolution. If the optional channel list is sent with the command, the channels are loaded in the order received, a measurement is made from each channel, in sequence, and stored.

If no channel list is sent with the command, the previously asserted channel list remains in effect. Furthermore, any channel that was previously closed remains closed and one measurement is made from that channel.

## Examples

| | |
|---|---|
| OUTPUT 901;"FWO0 9" | !Sets up channel list of channels 0 through 9. Channels 10 through 19 will also be used. Measurements are made on channel pairs and stored. |
| OUTPUT 901;"FWO" | !In this example no channel list is sent. Therefore, one measurement will be taken. If no channels are closed, this command can be used to make measurements from the front panel. |

## Notes

1. Refer to Chapter 5 for more information and examples.
2. [x,y,...z] refers to optional channel list. Rules for using the Channel List are given at the end of the Standard Commands.
3. Ideally [x,y,...z] should be on the same slot; i.e. addresses 0-9, 10-19, or 20-29. Each channel in the channel list is automatically paired with [x+10,y+10,...z+10] unless [x,y,...z] are between 20 and 29. In this case they are paired with [x-20,y-20,...z-20]. Channel pairs are closed simultaneously. Use caution therefore and know which channels you will be closing.
4. FWO always opens the last channel or pair of channels measured before closing the next two channels. When the 3421A is finished executing the command, the last channel in the list remains closed. If no channel list was sent, the 3421A leaves channels in the same state they were in prior to the command.
5. When the 3421A is addressed to talk, all readings will be sent in the order that they were taken (same order as the channel list).
6. Answer returned in form: +/-d.ddddddE+/-d cr lf
7. If no parameters are sent, then T2 (software single trigger) is executed. If parameters are sent, then T3 is executed.

# TEMPERATURE MEASUREMENTS

TEM[ y, z] [x,y, z] is optional channel list

## Description

TEM is used to take temperature measurements from T type thermocouples connected to a 44462A assembly. A software reference junction compensated conversion is made. The answer returned to the calculator is in degrees C with 5½ digit resolution.

If no channel list is sent with this command, the previously asserted channel list remains in effect. Furthermore, any channel that was previously closed remains closed and one measurement is made from that channel.

## Examples

```
OUTPUT 901;"TEM1,3,5,7-14"      !Sets up channel list for channels 1, 3, 5, and 7 through 14. Measurements are made on each
                                 channel and stored.

OUTPUT 901;"TEM"                !In this example, no channel number is sent. Therefore, the measurement will be made from
                                 whatever multiplexer channel is closed. If no channels are closed, the command can be used
                                 to make measurements from the front panel.
```

## Notes

1. Refer to Chapter 5 for more information and examples.
2. [x,y, z] refers to optional channel list. Rules for using the Channel List are given at the end of the Standard Commands.
3. The REFerence temperature will be taken on the same operation card as the channel specified. If no channels are specified, the REFerence temperature measurement will be made on the 44462A assembly, that has a multiplexer channel closed. If there are no multiplexer channels closed, the REF measurement will be made from the 44462A assembly in the lowest numbered slot. If there are no 44462A assemblies, an error will be generated.
4. TEM always opens the last channel measured before closing the next channel. When the 3421A is finished executing the command, the last channel in the list remains closed. If no channel list was sent, the 3421A leaves channels in the same state they were in prior to the command.
5. When the 3421A is addressed to talk, all readings will be sent in the order that they were taken (same order as channel list).
6. Answer in degrees C is returned in form: ±d.dddddE±d cr lf.
7. If no parameters are sent, then T2 (software single trigger) is executed. If parameters are sent, then T3 is executed.

# REFERENCE MEASUREMENT

REF[x] [x] is optional channel number

## Description

REF is used to determine the temperature of the reference junction on the 44462A assembly where channel [x] is located. The measurement is performed by executing a software single trigger, T2. If channel [x] is not sent, the measurement will be taken from any 44462A assembly where a multiplexer channel is closed. If there are no 44462A assemblies with a closed channel, the REF measurement will be made from the 44462A assembly with the lowest slot number. If there are no 44462A assemblies, an error will result. The answer returned by REF is in degrees C. Refer to chapter 5 for more information.

## Examples

```
10 OUTPUT 901;"REF1"            !Makes a reference junction temperature measurement on 44462A assembly in slot 0.
20 ENTER 901;A                  !Answer returned is in degrees C.
```

## Notes

1. Refer to Chapter 5 for more information on REFerence and TEMperature measurements. Also, there are examples in Chapters 3 and 4 using the REF command for thermocouple measurements.
2. [x] is an optional channel number.
3. The state of the 3421A changes to REFerence function (F5), autozero on, software trigger (T2) and 4½ digit resolution.

# FREQUENCY MEASUREMENTS

| FRQ[x,y,...,z] | [x,y,...,z] is optional channel list |
|---|---|

## Description

FRQ is used to set the 3421A for frequency measurements with a 1 second gate time and 6 digit resolution. The measurement is performed by executing a software single trigger, T2. If the optional channel list is sent, the channels are loaded in the order received, a measurement is made on each channel in sequence, and stored.

If no channel list is sent with the command, the previously asserted channel list remains in effect. Furthermore, any channel that was previously closed remains closed and one measurement is made from that channel.

## Examples

| | |
|---|---|
| OUTPUT 901;"FRQ1,3,6,7 14" | !Sets up channel list for channels 1, 3, 6, and 7 through 14. Measurements are made on each channel and stored. |
| OUTPUT 901;"FRQ" | !In this example, no channel list is sent. Therefore, the measurement will be made from any multiplexer channel that is closed. If no channels are closed, the command can be used to make measurements from the front panel. |

## Notes

1. Refer to chapter 6 for more information and examples.
2. [x,y,...,z] refers to optional channel list. Rules for using the Channel List are given at the end of the Standard Commands.
3. FRQ always opens the last channel measured before closing the next channel. When the 3421A is finished executing the command, the last channel in the list remains closed. If no channel list was sent, the 3421A leaves channels in the same state they were in prior to the command.
4. When the 3421A is addressed to talk, all readings will be sent in the order that they were taken (same order as the channel list).

# TOTALIZE COUNTER

| TOT[x] | [x] is optional channel number |
|---|---|

## Description

The TOTalize function is used to count events (totalize). The measurement is performed by executing a software single trigger, T2. If a channel is sent, the 3421A opens all other multiplexer channels, closes the specified channel, zeros the counter and starts counting. Maximum count is 65,535. If a channel is not specified, then no channels are changed. If the 3421A is addressed to talk, it will send the current subtotal without interrupting the totalize. IMPORTANT: The TOT command remains in effect until another command is received by the 3421A causing it to change states.

## Example

```
10 OUTPUT 901;"TOT3"          ! The TOTalize function is commenced on channel 3
20 WAIT 1000
30 ENTER 901;A                ! The current subtotal is entered into variable A
```

## Notes

1. Refer to Chapter 6 for more information and examples.
2. [x] is an optional channel number. If no channel is specified, the TOT function is executed with no channels changing state.
3. If [x] is not a multiplexer channel, an error will occur.

# READ DIGITAL INPUTS (8-bit word)

| | |
|---|---|
| RED[ | "n" specifies the slot number to read from |

## Description

RED[ is used to read the digital input word (8 bits) from the 44465A Digital I/O assembly in slot "n". The answer returned by the 3421A is a decimal number (0 to 255) which is equal to the sum of the values of the individual bits that are set. Refer to the bit value chart and to Chapter 6.

| Bit # | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Value | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

Bit Value Chart

## Examples

```
OUTPUT 901;"RED1"     ! Read the digital word from the 44465A assembly in slot number 1
ENTER 901;A           ! The value A is the sum of the values of the set bits.
```

For example, if A = 173 then bits 7, 5, 3, 2, and 0 were set (128 + 32 + 8 + 4 + 1 = 173). This means that the input port looks like

1 0 1 0 1 1 0 1

## Notes

1. Refer to Chapter 6 for more information and examples.

# DIGITAL WRITE

| | |
|---|---|
| WRT[,abc | "n" specifies the slot number to write to. abc is a decimal value (0 to 255) to be sent to board. |

## Description

The WRT command is used to write a digital word ([abc]) to the 44465A Digital I/O assembly output port in slot "n". The value [abc] is the sum of the values of the bits to be set. Refer to the bit value chart.

| Bit # | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| Value | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

Bit Value Chart

## Examples

```
OUTPUT 901;"WRT0,7"     ! This command would result in turning on switches 0, 1, and 2 on the 44465A assembly in slot 0
```

## Notes

1. Refer to Chapter 6 for more information and examples.

# READ DIGITAL INPUT BIT

| | |
|---|---|
| BITx[,y,...z] | x is a mandatory bit, [,y,...z] is optional bit list. |

## Description

The BITx command reads the digital input bit specified by x. The 3421A will return a value of +0.000E+0 if the bit value is low, or a +1.000E+0 if the bit value is high. A bit list, similar to a channel list can be set up. Refer to Chapter 6 for more information.

## Example

```
OUTPUT 901;"BIT16"     ! The 6th bit in slot 1 is read. Bits are numbered from 0 to 7
ENTER 901;A            ! The variable A contains the value the bit, either 0 or 1.
```

## Notes

1. Digital bits are numbered: 0-7, 10-17, 20-27. Numbers 08, 09, 18, 19, 28, and 29 are not valid digital bit numbers.
2. Refer to Chapter 6 for more information and examples.
3. Errors are sent as: 8.888E+8
4. Do not use T1 or T2 with the BIT command.

# CLOSE SINGLE CHANNEL, RELAY, OR BIT

| CLSx | x is mandatory |
|---|---|

## Description

Upon receipt of the CLSx command, the 3421A will determine the type of channel located at address "x". The following chart describes what will transpire, depending on the type of channel at the specified address.

Actuator: Closes actuator relay at address "x". Legal actuator channel numbers are (if so configured): 00, 01, 10, 11, 20, and 21.

Multiplexer: Opens all multiplexer channels then closes channel "x".

Digital: Sets bit "x". Legal Bit addresses are: 00-07, 10-17, and 20-27.

Non existent: Cannot comply error asserted (see SPOLL) and no channels change.

## Example

```
OUTPUT 901;"CLS05"        !This command would close channel or set bit 5 depending on what type of option assembly
                          is plugged into slot 0
```

## Notes

1. Refer to Chapter 5 and 6 for more information and examples.
2. CLS5 is the same as CLS05.

# CLOSE CHANNEL PAIRS

| CLPx | x is a mandatory value |
|---|---|

## Description

The CLPx command first causes all multiplexer channels to be opened and then closes channels x and x + 10. If channel x is between 20 and 29, then channels x and x-20 will be closed. If either x or its pair is not a multiplexer channel, the cannot comply error will be asserted (see SPOLL) and no channels change state.

## Example

```
OUTPUT 901;"CLP3"     ! Channels 3 and 13 will be closed.
OUTPUT 901;"CLP23"    ! Channels 23 and 3 will be closed.
```

## Notes

1. Refer to Chapter 5 for more information and examples.

# OPEN CHANNEL

| OPN[x] | x is an optional value |
|---|---|

## Description

Upon receipt of the OPN command, the 3421A first determines what type of channel is specified by "x" and then performs the following:

"x" not sent: All channels (multiplexer, actuator, switches (see UC command)) opened and all digital output bits cleared.

Actuator: opens relay.

Multiplexer: Opens channel. If that channel had been closed with a pair (CLP command) its pair would also be opened. For example, if you sent CLP3, then channels 3 and 13 would be closed. If you then sent OPN 3 or OPN 13 then both channels 3 and 13 would be opened.

Digital: Clears bit "x".

Switch: (those relays closed by the UC command), opens relay "x".

"x" non existent: No channels change, cannot comply error asserted (see SPOLL).

## Example

```
OUTPUT 901;"OPN3"         ! Opens channels 3 (or clears bit 3) If Channel 3 was closed with a pair (either channel 13 or
                          23), that channel would also be opened.
```

## Notes

1. Refer to Chapters 5 and 6 for more information and examples.

# CHANNEL LIST

The series of channels specified in a channel list must follow these rules

1. The default channel list (asserted at power on or reset) is all multiplexer channels 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. See chapters 5 and 6 for more information.

2. Channel numbers are separated by commas. However, a dash may be used to signify a contiguous set of channels (i.e., DCV2 9). Any command that specifies a channel must be seperated from subsequent commands by either a colon (:), a semicolon (;), or a Carriage Return/Line Feed but not a comma. If the last character in the command string is a comma, an error will be generated.

3. To take a burst of 30 readings on one channel, lead the channel list with the channel number. For example, DCV6:5 will take 30 DC Voltage readings on channel 5.

4. The mnemonic determines what type of channel can be loaded into the channel list. In other words, if channel 1 is configured as an actuator channel, 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 is generated (see SPOLL) and the command is aborted. If channels x-y is received and some channels in between and including x and y are the wrong type of channels for the command, they are not loaded into the list and the error message is not generated. The remainder of the channels are loaded into the list.

5. Leading zeros are ignored, that is, DCV000,10 means DCV10.

6. All syntax following a decimal point is ignored except for commas, dash, semicolon, colon, Carriage Return (cr), or Line Feed (lf). DCV2.2 means DCV2.

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

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

9. All lower case letters are interpreted as upper case ASCII characters, other than "a", "x" result in an error. In other words, DcV 21 is the same as DCV21.

10. Terminators are required after any command (Standard or Advanced) that either specifies a channel or a decimal value, when that command is to be followed by another command. For example, the 'Mx' command is used to set the SPC mask. This command can have a decimal value 'x' of between 0 and 255. Therefore, this command must be followed by a terma for if another command is to follow it; e.g., 'OUTPUT 801; "M1:T0"'. Valid terminators are a colon (:), a semicolon (;), a Carriage Return or Line Feed; but not a comma (,).

# Advanced Commands

## A/D ( Voltmeter, Counter)

| Function, Command | Range Codes R1 | R0 | R1 | R2 | R3 | R4 | R5 | R6 | R7 |
|---|---|---|---|---|---|---|---|---|---|
| | RA1 = Auto Range ON<br>RA0 = Auto Range OFF | | | | | | | | |
| All functions off, F0 | * | * | * | * | * | * | * | * | * |
| DC Volts, F1 | .3V | 3V | 30V | 300V | * | * | * | * | * |
| AC Volts F2 | * | 3V | 30V | * | * | * | * | * | * |
| 2-Wire Ohms, F3 | * | * | * | 300Ω | 3KΩ | 30KΩ | 300KΩ | 3MΩ | 30MΩ |
| 4 Wire Ohms, F4 | * | * | * | 300Ω | 3KΩ | 30KΩ | 300KΩ | 3MΩ | 30MΩ |
| REFerence, F5 (See Standard command REF) | The Range is automatically set by the REF command | | | | | | | | |
| TEMperature, F6 (Using T type Thermocouples. See Standard Command TEM ) | The Range is automatically set by the TEM command | | | | | | | | |
| Frequency, F7 | Gate Times G-1 = 1 sec., G0 = 1 sec., G1 = 10 secs | | | | | | | | |

* Indicates an invalid combination of function and range codes

Voltmeter Autozero

Z0 = Auto zero OFF
Z1 = Auto zero ON

Number of Digits of Resolution

N3 = 3½ digits
N4 = 4½ digits
N5 = 5½ digits

Trigger

T0 = Enable channel list measurements and reading storage but do not take readings. Will trigger on either T3, DT, or HP-IB/HP IL TRIGGER command. (With a 41C/CV, the TRIGGER command causes a timeout after 10 seconds. The T3 command is recommended as an alternative.)

T1 = Internal trigger for readings initiated by a read command, i.e., ENTER 901. (Triggers only on read)

T2 = Software trigger. Takes one measurement on current channel.

T3 = Triggers (makes measurements) with channel list and reading storage

Note: If F0 is asserted and the 3421A receives either T1, T2 or T3, an error will be generated and -8.88888E+8 will be sent.

DTix = Executes T3 if bit "x" on Digital Input port (slot) "i" goes low (i.e., no current is passing through the port). Note: If any information is passed through the interface prior to the event (trigger) the digital trigger function will be aborted.

## Example

To set the 3421A to AC Volts function, 3½ digit resolution, trigger hold, execute the following command:

```
OUTPUT 901;"F2N3T0"
```

# Digital Control Commands

## Monitor High (bit)

| MHx (x = digital bit address) |
|---|

### Description

Sets bit 3 (event occurred) in Status Register when the specified bit equals a "1" (high). Therefore, an SRQ interrupt will be sent to the computer. When the 3421A is addressed to talk, it will send the status of the digital input word (8-bits) at the time the bit went high.

### Example

```
OUTPUT 901;"M8"                    ! Set SRQ Mask for EVENT OCCURRED.
OUTPUT 901 USING "#,K" ; "MH15"    ! This command monitors bit 5 in slot 1 (Digital I/O)
```

### Notes

1. After setting the 3421A for the monitor command, no further communication should be allowed on the interface (HP-IL or HP-IB). The monitor command may be aborted if any communication occurs.

2. If you are using the 3421A with the HP-IB interface, you will need to execute the command: SEND 7; UNL (or its equivalent) to "unlisten" the 3421A. If this is not done, the 3421A will not interrupt the computer.

## Monitor Low (bit)

| MLx (x = digital bit address) |
|---|

### Description

Sets bit 3 (event occurred) in Status Register when the specified bit equals a "0" (low). Therefore, an SRQ interrupt will be sent to the computer. When the 3421A is addressed to talk, it will send the status of the digital input word (8 bits) at the time the bit went low.

### Example

```
OUTPUT 901;"M8"                    ! Set SRQ mask for EVENT OCCURRED.
OUTPUT 901 USING "#,K" ; "ML02"    ! Monitor bit 2 on slot 0 (Digital I/O)
```

### Notes

1. After setting the 3421A for the monitor command, no further communication should be allowed on the interface (HP-IL or HP-IB). The monitor command may be aborted if any communication occurs.

2. If you are using the 3421A with the HP-IB interface, you will need to execute the command: SEND 7; UNL (or its equivalent) to "unlisten" the 3421A. If this is not done, the 3421A will not interrupt the computer.

# Monitor Slot (word)

| | |
|---|---|
| MNi | Monitor Slot "i" |

## Description

This instruction reads digital input port on slot "i", Exclusive OR's it with the XOR mask (see XR[abc] command), AND5 the result with the AND mask (see AN[abc]) and if the final result equals zero it sets bit 3 in the Status Register. This command does not automatically set the SRQ Mask. An SRQ interrupt will be generated if bit 3 in the SRQ Mask is set, see "M" in the Advanced Commands.

## Example

```
OUTPUT 901;"MB"                    ! Set SRQ mask for EVENT OCCURRED.
OUTPUT 901 USING "#,K" ; "MN2"     ! Monitor slot 2
```

## Notes

1. After setting the 3421A for the monitor command, no further communication should be allowed on the interface (HP-IL or HP-IB). The monitor command may be aborted if any communication occurs.

2. If you are using the 3421A with the HP-IB interface, you will need to execute the command: SEND 7, UNL (or its equivalent) to "unlisten" the 3421A. If this is not done, the 3421A will not interrupt the computer.

# Exclusive OR Mask (for MN command)

| | |
|---|---|
| XR[abc] | Exclusive OR mask, abc] represents a decimal number 0 255. |

## Description

The value [abc] is the sum of the values of the individual bits you want set in the mask. As a general rule, the XR mask is set to the bits you want to interrupt on when they go true (1). If no number is received, the mask is set to all zeros. See Bit value chart in chapter 6.

## Example

```
OUTPUT 901;"XR53"    !Sets the Exclusive OR mask to bits 5, 4, 2, and 0. (32 + 16 + 4 + 1 = 53)
```

# AND Mask (for MN command)

| | |
|---|---|
| AN[abc] | AND Mask, [abc] represents a decimal number 0 255. |

## Description

The value [abc] is the sum of the values of the bit you want to set in the mask. As a general rule, the AN mask is set to the bits you want to monitor to cause the interrupt. If no number is received with the AN command, the mask is set to all zeros. See bit value chart in Chapter 6.

## Example

```
OUTPUT 901;"AN135"    ! Set the AND mask to bits 7, 2, 1, and 0. (128 + 4 + 2 + 1 = 135)
```

# Digital Set (word)

| | |
|---|---|
| DSi,[abc] | "i" is the slot number for the Digital I/O option [abc] is a decimal value you wish to set the word to. |

## Description

This command "sets" the digital output port switches of the option card in slot "i" to the value [abc]. All switches not specified by [abc] remain unchanged. [abc] is the sum of the values of the individual bits you want set.

## Example

```
10 OUTPUT 901,"DS1,53"    ! Set the word "53" (bits 5, 4, 2, and 0) in slot 1.
```

# DIGITAL CLEAR

| | |
|---|---|
| DCi,[abc] | "i" is the slot number for the Digital I/O option, [abc] is the decimal value you want to set the word to. |

## Description

This command "clears" the digital output port switches of the option card in slot "i" to the value [abc]. All switches not specified by [abc] remain unchanged. [abc] is the sum of the values of the individual bits you want cleared.

## Example

```
10 OUTPUT 901,"DC2,17"    ! Clear bits 4 and 0 in slot 2
```

# Channel Control Commands

## READ CHANNEL LIST

| | |
|---|---|
| RL | Read channel List |

### Description

This command allows you to read back to the computer the current channel list of the 3421A. The channel list is read back in the same order it was assigned. If a place in the list is empty, the place will be marked by "99".

### Example

```
10 OUTPUT 901"LS1 7"      !Set up channels 1 through 7 as channel list
20 OUTPUT 901,"RL"        ! Read channel list
30 FOR I = 1 TO 30
40 ENTER A(I)             ! Enter and display the channel list
50 DISP A(I)
60 NEXT I
```

The Channel List would be read back as: 1, 2, 3, 4, 5, 6, 7, 99, 99, 99, . . . until 30 numbers are read back.

## LOAD SINGLE CHANNELS (into channel list)

| | |
|---|---|
| LS[x,y, . . .z] | Load channels [x,y, . . .z] into the channel list |

### Description

Use the LS command to load the channel list with single channels (see also LP command). If the voltmeter or counter is also set up, a T3 command will open all multiplexer channels, close the first channel in the list, and initiate readings on the channel list and store them. The channels may be in any order.

### Example

```
10 OUTPUT 901,"LS1 6,7"     ! Load channels 1,2,3 4,5, and 7 into the channel list.
```

## LOAD CHANNEL PAIRS (into channel list)

| | |
|---|---|
| LP[x,y, . . .z] | Load channels [x,x+10,y,y+10, . . .z,z+10] into channel list. |

### Description

Use the LP command to load the channel list with channel pairs. Channels x and x + 10 are closed simultaneously. If a channel number (e.g., x = 24) is greater than 20, then its paired channel will be x-20 (e.g., 4).

### Example

```
10 OUTPUT 901,"LP12 15"     ! Channel pairs 12&22, 13&23, 14&24, 15&25 are loaded into the
                            channel list.
```

# CHANNEL LIST POINTER

SI1 Scanner increment

## Description

Opens the currently closed multiplexer channel and closes the next channel in the list. No measurements are taken

SI0 - Reset Pointer

## Description

Resets channel list pointer to beginning of channel list. No channels are opened or closed and no measurements are taken

## Example

```
10 OUTPUT 901,"SI1"        ! Increments multiplexer
```

# UNCONDITIONALLY CLOSE CHANNEL

UCx Unconditionally Close channel x.

## Description

The channel specified by "x" is closed without opening any other channels. Also, if "x" is a digital output bit, the bit will be set

WARNING

USE EXTREME CARE WITH THIS COMMAND. IT IS POSSIBLE TO HAVE TWO OR MORE CHANNELS CLOSED SIMULTANEOUSLY WITH THIS COMMAND. DAMAGE TO THE INSTRUMENT OR CUSTOMER TRANSDUCERS OR OTHER INSTRUMENTATION MAY OCCUR

## Example

```
10 OUTPUT 901,"UC12"       ! close channel 12 regardless of what type it is.
```

# Instrument Control Commands

## RESET

| | |
|---|---|
| RS | Reset |

### Description

This command is used to reset the 3421A. The 3421A goes through its internal self test and goes to the following states:

1. All multiplexer and actuator channels are opened.
2. All digital output bits are cleared.
3. Voltmeter is set to: DC Volts, Autorange on, Autozero on, 5½ digits resolution, internal trigger.
4. Counter is set to 1 second gate time.
5. Reads rear panel switches and responds accordingly.
6. Channel list is initialized to all available multiplexer channels from lowest number to highest number.
7. SRQ interrupt generated if self test failed.
8. The HP-IL address is not changed.
9. Reading storage buffer is empty.

### Example

```
10 OUTPUT 901;"RS"          ! Reset the 3421A
```

## DISPLAY NUMBER

| | |
|---|---|
| DNx | x is optional numbers 0-29 |

### Description

The number "x" (0 to 29) will be displayed on the 3421A display. No channels are changed and no measurements will be made. However, any channel numbers previously displayed will disappear.

### Example

```
10 OUTPUT 901;"DN6"         ! This will display the number 6 on the 3421A display
```

### Notes

1. Sending DN without x returns the 3421A to normal display mode.

## SET SRQ MASK

| | |
|---|---|
| M[n] | Set SRQ Mask to value "n" |

### Description

This command is used to set the SRQ mask inside the 3421A. Only bits 0, 3, and 5 can be masked. Bit 1 is masked by the Power on SRQ switch on the rear panel of the 3421A. The value "n" is a decimal value equal to the sum of the values of the bits you want to set. When a 1 to 1 correspondence of set bits in the Status Register and set bits in the SRQ mask occurs, an SRQ interrupt will be sent to the computer.

| Bit 7 N/A | Bit 6 SRQ | Bit 5 Abnormal Condition | Bit 4 Low Batt | Bit 3 Event Occurred | Bit 2 Self Test Error | Bit 1 PWR on Reset | Bit 0 Data Ready |
|---|---|---|---|---|---|---|---|

### Example

```
10 OUTPUT 901;"M1"          !Sets SRQ mask for Data Ready
```

# READ STATE REGISTERS

SR read State Registers

## Description

When the 3421A receives this command, 24 decimal numbers will be sent to the computer. Each decimal number (0 to 255) represents one state register. The state registers are used to determine the exact status of the 3421A. The first four registers are error registers and are used to determine the exact nature of errors. These error registers are cleared after all four are read. For HP-IB, register 5 must also be read using an additional ENTER statement. The remaining registers are used to determine the current state of the 3421A, i.e., which option assemblies are available in the 3421A, the current measurement function (whether DC Volts, ohms, etc.), measurement range, which multiplexer and actuator channels are closed, and the setting of the various masks. These registers are not cleared after reading. If the 3421A receives another command before it has sent all of the 24 registers, it will stop sending them.

## Example

```
10 DIM A(24)
20 OUTPUT 801, "SR"          ! This line sends the Status Register command
30 FOR I = 1 TO 24
40 ENTER 801, A(I)           ! These three lines read back the 24 registers
50 DISP A(I)
60 NEXT I
```

The following describes each of the registers. The value returned from each register is the sum of the values of the bits that are set. Chapter 3 has a short BASIC language program that will read all 24 registers and decode them on a bit by bit basis.

## Register 1: Status Register (see SPOLL, Chapter 3)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Always zero | SRQ | Abnormal Condition | Low Battery | Event Occured (MN,ML, MH) | Self Test Error | Power on Reset | Data Ready |

## Register 2: Error

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Tried to load channel list with more than 30 channels | Can't do T3 since chan list is empty | Can't do TOT,MH, ML,MN, OT while Battery is low | Option specified in command does not exist in that slot | invalid syntax | Addressed to talk but no data ready | Triggered but HO asserted |

## Register 3: Hardware Error (see 3421A Service Manual)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| 10 MΩ test failed | RAM U603 failed | RAM U604 failed | μP RAM failed | A-D Slope Error | ROM 0 check sum error | ROM 1 checksum error | Cal RAM check sum error |

## Register 4: Calibration error (see 3421A Service Manual)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | A-D error | Cal RAM bad | Cal attempted Cal RAM not enabled | Invalid CAL zero | Invalid Cal signal | Invalid Cal number | Invalid Cal function or range |

NOTE: Those bits specified as Not Defined may be either a "1" or a "0".

## Register 5: Status of the SRQ Mask (see SPOLL in Chapter 3)

| Bit 7 | Bit 6* | Bit 5 | Bit 4* | Bit 3 | Bit 2* | Bit 1** | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | SRQ (always 1) | 1 = SRQ if abnormal condition occurs | Low battery (always 1) | 1 = SRQ if event occurs (MNEMI DT) | Self Test failed (always 1) | 1 = SRQ if Power on reset occurs | 1 = SRQ if data ready |

* The bits labeled as "always 1" are not maskable. When the event occurs, the SRQ interrupt message will be sent to the controller.

** This bit or feature is enabled/disabled by the POWER ON SRQ switch on the rear panel of the 3421A.

## Register 6: Option Boards Available

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Slot 2 is digital option | Slot 1 is Digital option | Slot 0 is Digital option | always zero | Slot 2 is mux option | Slot 1 is mux option | Slot 0 is mux option |

## Register 7: Actuator Channels Available

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | 1 = actuator channel 21 | 1 = chan nel 20 | 1 = chan nel 11 | 1 = chan nel 10 | 1 = chan nel 1 | 1 = chan nel 0 |

## Register 8: Actuator Channels Closed

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | 1 = actuator channel 21 closed | 1 = actuator chan nel 20 closed | 1 = actuator chan nel 11 closed | 1 = actuator chan nel 10 closed | 1 = actuator channel 01 closed | 1 = actuator chan nel 00 closed |

## Registers 9 and 10:

Register 9 contains the channel address when a multiplexer channel is closed. If channel pairs were closed, Register 10 contains the paired channel.

| Bit 7 Bit 6 Not Defined | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | |
|---|---|---|---|---|---|---|---|
| Slot 0 | 0 | 0 | 0 | 0 | 0 | 0 | Channel 0 |
| Slot 1 | 0 | 1 | 0 | 0 | 0 | 1 | Channel 1 |
| Slot 2 | 1 | 0 | 0 | 0 | 1 | 0 | Channel 2 |
| | | | 0 | 0 | 1 | 1 | Channel 3 |
| | | | 0 | 1 | 0 | 0 | Channel 4 |
| | | | 0 | 1 | 0 | 1 | Channel 5 |
| | | | 0 | 1 | 1 | 0 | Channel 6 |
| | | | 0 | 1 | 1 | 1 | Channel 7 |
| | | | 1 | 0 | 0 | 0 | Channel 8 |
| | | | 1 | 0 | 0 | 0 | Channel 9 |
| | X | X | 1 | 1 | 1 | 1 | no channel closed |

Bit definition for Registers 9 and 10 are the same.

NOTE: Those bits specified as Not Defined may be either a "1" or a "0".

## Registers 11 through 16: Indicates which relay channels were closed by the UC command

### Register 11

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | 1 chan 4 closed | 1 chan 3 closed | 1 chan 2 closed | 1 chan 1 closed | 1 chan 0 closed |

### Register 12

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | 1 chan 9 closed | 1 chan 8 closed | 1 chan 7 closed | 1 chan 6 closed | 1 chan 5 closed |

### Register 13

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | 1 chan 14 closed | 1 chan 13 closed | 1 chan 12 closed | 1 chan 11 closed | 1 chan 10 closed |

### Register 14

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | 1 chan 19 closed | 1 chan 18 closed | 1 chan 17 closed | 1 chan 16 closed | 1 chan 15 closed |

### Register 15

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | 1 chan 24 closed | 1 chan 23 closed | 1 chan 22 closed | 1 chan 21 closed | 1 chan 20 closed |

### Register 16

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | 1 chan 29 closed | 1 chan 28 closed | 1 chan 27 closed | 1 chan 26 closed | 1 chan 25 closed |

### Register 17: Functions

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | Not Defined | Not Defined | | | |
| | | | | | No functions asserted 0 | 0 | 0 |
| | | | | | DC Volts 0 | 0 | 1 |
| | | | | | AC Volts 0 | 1 | 0 |
| | | | | | 2 Wire Ohms 0 | 1 | 1 |
| | | | | | 4 Wire Ohms 1 | 0 | 0 |
| | | | | | Reference Temperature 1 | 0 | 1 |
| | | | | | Temperature (T type thermocouple) 1 | 1 | 0 |
| | | | | | Frequency 1 | 1 | 1 |

NOTE: Those bits specified as Not Defined may be either a "1" or a "0".

## Register 18: Ranges

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 | |
|---|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | | | | | | | |
| Counter | 1 Second | 0 | 0 | 0 | 0 | 0 | 0 | NOT USED |
| Gate Time | 1 Second | 0 | 0 | 0 | 0 | 0 | 1 | R1 |
| Codes | 10 Second | 1 | 1 | 0 | 0 | 1 | 0 | R0 |
| | | | | 0 | 0 | 1 | 1 | R1 Voltmeter |
| | | | | 0 | 1 | 0 | 0 | R2 Ohms |
| | | | | 0 | 1 | 0 | 1 | R3 Codes |
| | | | | 0 | 1 | 1 | 0 | R4 |
| | | | | 0 | 1 | 1 | 1 | R5 |
| | | | | 1 | 0 | 0 | 0 | R6 |
| | | | | 1 | 0 | 0 | 1 | R7 |

## Register 19: Voltmeter status

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| 1 Cal enabled | Not Defined | | | 1 60Hz 0 60Hz integration time | 1 auto zero on 0 auto zero off | 1 auto range on 0 auto range off | 1 internal trigger |

| | | |
|---|---|---|
| 0 | 0 | 10 (Trigger hold) |
| 0 | 1 | 11 |
| 1 | 0 | 12 |
| 1 | 1 | 13 |

## Register 20: Number of Digits of Resolution

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | Not Defined | Not Defined | Not Defined | | |
| | | | | | invalid | 0 | 0 |
| | | | | | 5½ digit res | 0 | 1 |
| | | | | | 4½ digit res | 1 | 0 |
| | | | | | 3½ digit res | 1 | 1 |

## Register 21: Channel List

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| 1 channel list is digital bits 0 channel list is max channels | Not Defined | Not Defined | Not Defined | Not Defined | 1 SOT function on | Not Defined | Not Defined |

## Register 22: Display Mode

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|
| Not Defined | Not Defined | Not Defined | Not Defined | Not Defined | 1 DN mode on 0 DN mode off | Not Defined | Not Defined |

## Register 23: AND mask (set by AN[abc] command)

## Register 24: Exclusive-OR Mask (set by XR[abc] command)

NOTE Those bits specified as Not Defined may be either a "1" or a "0"

# CHAPTER

# 4

# CHAPTER 4
# Programming With the -hp- Model 41C/CV Calculator

## Introduction

Your -hp- Model 3421A was designed to interface with a wide variety of calculators and computers over the Hewlett-Packard Interface Loop (HP-IL). In the last chapter we saw how to use the 3421A with BASIC language controllers. This chapter discusses the remote operation and programming of the 3421A from the -hp- 41C/41CV family of handheld calculators. The many features of the 3421A combined with the computational power of the 41C/CV calculator provides for a low cost, flexible measurement and control system. In addition, plotter/printers, cassette mass storage drives and other HP-IL instruments can easily be added to the loop.

This chapter shows you how to execute simple, one command instructions from the calculator to control the 3421A and then read the measurement data back. Later in the chapter, we'll discuss interface control and the development of powerful programs to solve your measurement needs. Last, you'll look at several application programs including a simple data logger with a printer and cassette drive.

Before beginning this chapter you will want to have read Chapters 1 and 2 of this manual. Those chapters will familiarize you with the many features of the 3421A and its command set. You will also find it helpful to read the -hp- Model 41C/41CV Owners Handbook and Programming Guide (-hp- part number 00041-90313) and the -hp- Model 82160A HP-IL Module Owners Manual (-hp- part number 82160-90001).

Special Note. The Data Acquisition Control Pac ROM (-hp- part number 44468A) for the 41C/CV provides friendliness for controlling the 3421A not afforded by the calculator alone. Therefore, if you have the DA/C Pac it may not be necessary to read this chapter. Read the manual provided with the ROM Pac instead. If you decide to write your own custom programs using the subprograms provided with the ROM Pac, this chapter provides a basis for program writing.

## Examples Format

The many examples in this chapter are designed to enhance your understanding of programming the 41C/CV to control the 3421A. The examples show the keystrokes used in entering a command or program line from the calculator keyboard. Also shown is the calculator display for each line as it has been entered. Enter the programs as shown. If you make a mistake when entering a command you can generally use the correction key (back arrow) to edit the line. If you are entering a program line, use the Back Step key [BST] or the Single Step key [SST]. Refer to the Owner's Handbook and Programming Guide for more operating and programming information for the 41C/CV.

## Sending Instructions to the 3421A.

Using a programmable calculator to control the 3421A allows for greater flexability and control than afforded by a front panel. The calculator effectively becomes the 3421A's front panel. Of course this involves both sending instructions to the 3421A and receiving data from it. Let's begin by seeing how a simple instruction is sent .

Do This *

Connect only the 3421A in the loop with the 41C/CV.

| Keystrokes | Comments | 41C/CV Display |
|---|---|---|
| [ALPHA] DN5 [ALPHA] | You can replace '5' with any number between 0 and 29, e.g., DN27. Note that the shift key is required to enter numbers into the Alpha Register. | DN5 |
| [XEQ] [ALPHA] OUTA [ALPHA] | | OUTA |

* If this example doesn't work, turn off both the 3421A and the calculator. Make certain that the HP-IL connections have been made. Turn the 3421A on first and wait until the display clears then turn the 41C/CV on. Try running the initialization program shown later in this chapter.

Let's take a closer look at what you did. First, the message DN5 was stored into the alpha register. DN (Display Number) is called a command code and tells the 3421A to display the number 5. Second, the command OUTA (OUTput Alpha register) was executed (XEQ). Since the 3421A is the only device in the loop, it received the instruction and displayed the number. Try the command again using a different number.

You should now execute the DN command without a number to clear the 3421A from the display number (DN) mode. That is:

[ALPHA] DN [ALPHA]

[XEQ] [ALPHA] OUTA [ALPHA]

There are several command codes that the 3421A recognizes. The blue pages at the end of the previous chapter describe the codes and give a brief example of how they are used.

## Sample Problem

Suppose you need to make an AC voltage measurement from channel 12. The easiest way to do this would be to use the Standard command, ACV12. The sequence would look like:

[ALPHA] ACV12 [ALPHA]

[XEQ] [ALPHA] OUTA [ALPHA]

The command ACV12 means that an AC Voltage measurement is to be taken on channel 12. OUTA (OUTput Alpha register) is an instruction causing the contents of the Alpha register, in this case ACV12, to be sent through the interface to the 3421A. When the 3421A receives the command, the measurement is made.

## Programming Hints

If the same type of measurement is to be made on several channels, all the channels can be specified in one command. In other words, ACV12,13,15-19 specifies an AC Voltage measurement on channels 12, 13, 15, 16, 17, 18, and 19. Channel 12 is measured first and the measured value is stored in the 3421A's reading storage. Then channel 13 is measured and the measured value stored. Finally, channel 19 is measured and that value is stored.

Later, when you want to read back the measured voltages (see the IND command later in this chapter), the voltage from channel 12 will be read back first, then from channel 13, and so on until the voltage from channel 19 is read back.

Instructions for the 3421A are sent as a series of 7-bit ASCII characters. If more than one instruction or piece of data is sent at one time, they must be separated

by a colon (:). Characters that are ignored are blanks and plus (+). All other punctuation and character sequences that are not recognized by the 3421A will result in a syntax error. In other words, Dc V 21 is interpreted exactly the same as DCV21.

The series of channels specified in this way defines a "Channel List". The following rules apply to the channel list:

a. The default channel list (asserted at power on or reset) becomes all available multiplexer channels is numerical sequence. The DCV, ACV, TWO, FWO, TEM, FRQ, LS and LP commands can be used to alter or load the channel list. It can also be loaded with digital input bit numbers by the BIT command. See chapters 5 and 6 for more information.

b. Channel numbers are separated by commas. If the last character sent is a comma an error will be generated. A dash may be used to signify a contiguous set of channels (i.e. x-y). When using the Advanced Commands, any command that specifies a channel must be separated from subsequent command by a valid terminator. For example, F1RA1LS5-9;T3. If the last character in any command string is a comma, an error will be generated.

c. No more than 30 channels are accepted. Valid channel numbers are 0 through 29.

d. To take a burst of 30 readings from one channel, load the channel list with that one channel number. For example, to take DC voltage readings from channel 5, execute: DCV5-5.

e. The mnemonic determines what type of channels are loaded into the list. In other words, if channel 1 is configured as an actuator channel, it should not be specified for any type of measurement (i.e. DC Voltage or bit 1, etc.). If an attempt is made to load the list with an improper type of channel, a syntax error is sent (see INSTAT) and the command is aborted. If x-y is received where channels between and including x and y are of the wrong type, they are not loaded into the channel list and the error message is not sent. The remainder of the channels are loaded into the list

f. Leading zeros and spaces are ignored; i.e., 00019 is channel 19.

g. Generally, all syntax following a decimal point is ignored except for comma, dash, semicolon, colon, Carriage Return (cr), and Line Feed (lf). I.e.LS2.345 loads channel 2.

h. Exponents are not allowed and cause a syntax error; i.e., DCV2.345E+1 would cause an error and no channel list is accepted.

# Receiving Data From the 3421A

Not only can the 3421A be controlled by the 41C/CV calculator, but it can also talk to the calculator. The 3421A can send measurement data and status information about the mainframe and the digital option cards. The calculator can then process the measurement data or status information as necessary.

From the last section we saw how to program the 3421A to take an AC voltage measurement from channel 12. Now let's see how to transfer the measurement data from the 3421A to the calculator.

| Keystrokes | Comments | 41C/CV Display |
|---|---|---|
| [ALPHA] ACV12 [ALPHA] | AC Voltage measurement on channel 12. | ACV12 |
| [XEQ] [ALPHA] OUTA [ALPHA] | OUTput Alpha Register. | OUTA |
| [XEQ] [ALPHA] IND [ALPHA] | INput Decimal number. | IND<br><br>(Measured Value) |

IND (INput Decimal) is an instruction that causes the 3421A to talk to the calculator, giving measurement or status information. The measurement will appear in the calculator's display as well as in the X-register. Since the reading is in the X-register it is ready to be operated on by the calculator. For example, you could take the log of the reading by simply pressing the **LOG** key.

If a channel list were sent out with the command, e.g. ACV12,13,15-19, the reading from the first channel is sent the first time IND is executed, The second execution of IND causes the reading from the second channel to be sent. Subsequent executions of IND cause the readings from the remaining channels to be sent to the calculator. The error message, -8.88888E+8, will be sent if an error occurs—such as if IND is executed after the last channel has been read.

Looking closely at what we have done so far, we can see the beginnings of a very simple program. A program instructs the 3421A to do something (either make a measurement or read the status, etc.) and then enter the result into the calculator.

The program will need to be completed by adding a label and an **END** statement. Look at the program listing below and compare it to the earlier example for reading the AC voltage on channel 12.

```
01*LBL "ACVOLTS"   – Label
02 "ACV12"         – Load the command into the Alpha register
03 XEQ "OUTA"      – OUTput Alpha register command
04 XEQ "IND"       – INput Decimal value from channel 12
05 END             – END of program
```

## HP-IL Interface Control

Before pursuing further the subject of program writing, let's look at some special HP-IL commands. In the examples we've looked at so far, commands like IND, OUTA, and INA have been used. These commands are called Interface Control commands. Now, you'll learn what these and other commands mean and how they are used. The control commands allow you to directly specify a device to perform a function, send or receive information, or control the interface loop. These control commands also allow you to use more than one 3421A in the interface loop.

The eleven Interface Control Commands are listed below with a very brief explanation of what they do. After the list, we'll look at each one individually to see how it is used and to see more of what it does. You may also want to read the -hp- Model 82160A HP-IL Module Owners Manual.

| | |
|---|---|
| SELECT | Select a particular device or instrument |
| OUTA | Output the Alpha register to the selected device |
| IND | Input decimal number from selected device |
| INA | Input from selected device to Alpha register |
| TRIGGER | Triggers all devices previously set to Listen mode plus the selected device |
| INSTAT | Input the status byte from selected device |
| PWRDN | The Power-Down command sets all devices to the standby power condition |
| PWRUP | The Power-Up command returns all devices to full operating power conditions |
| FINDID | Find the HP-IL address of a particular device |
| AUTOIO | Set the HP-IL interface to the Auto mode (default) |
| MANIO | Set the HP-IL interface to the Manual mode |
| REMOTE | Set the selected device to Remote mode (Not needed for 3421A, it is always in remote) |
| LOCAL | Set selected device to Local mode (Local not implemented on the 3421A) |
| LISTEN | Set selected device to Listen mode |

# SELECT

## Example

[XEQ] [ALPHA] SELECT [ALPHA]

## Comments

The SELECT command is used to determine which HP-IL device will receive commands from the calculator—that is, become the "selected" device. You must put the HP-IL address of the device into the X-register prior to executing the SELECT command.

# OUTA

## Example

[ALPHA] DCV12,13,15-19 [ALPHA]

[XEQ] [ALPHA] OUTA [ALPHA]

## Comments

The command OUTA (OUTput Alpha register) causes the contents of the Alpha register to be output to the selected device. In the example shown above, the alpha register is loaded with the command string: ACV12,13,15-19.

## Example

[XEQ] [ALPHA] IND [ALPHA]

## Comments

The IND (INput Decimal) command retrieves an ASCII-coded numeric value from the selected device and places it into the X-register of the calculator. If the 3421A has been given a measurement command (such as DCV) and then receives the IND command, the 3421A becomes a talker and outputs one measurement value in the form:

+/-d.ddddddE+/-d CR LF (5½ digit mode)

where d represents a single digit. The calculator automatically places the decimal point to remove the exponent. If the 3421A is in the 4½ digit mode, only the 4½ digits will be sent, i.e., +/-d.dddddE+/-d CR LF. In the 3½ digit mode, only the 3 1/2 digits will be sent. CR is Carriage Return and LF is Line Feed. CR LF is a standard end-of-line terminator and does not show in the display.

The message: +9.99999E+9 (5½ digit mode) indicates one of the following conditions:

a. Voltmeter overload
b. Counter overflowed in TOT mode
c. Temperature out of range, i.e., reference not between 0 and 60 degrees C or thermocouple voltage not between 6 and 20 millivolts.

Error conditions caused by the voltmeter, channel list, etc. are indicated by: -8.88888E+8 (5½ digit mode) The error message for digital I/O errors is: 888. Essentially there are 10 error conditions:

a. Function F0 is asserted and the 3421A received a trigger command.

b. A hardware error such as the calibration RAM checksum error or A/D slope error.

c. The 3421A is addressed to talk but it has nothing to send (i.e., it was not told to take a measurement).

d. A syntax error occurred

# IND (Cont'd)

e. A command was given but the appropriate option board does not exist in the slot specified.

f. An attempt was made to load the channel list with more than 30 channels.

g. An attempt is made to increment the channel list and take a reading (T3) but the channel list is empty.

h. The 3421A internal battery is low but an attempt was made to execute TOT, MH, ML, or MN.

i. A calibration error (see the 3421A Installation and Service manual).

j. Failed Self Test.

An example is given with the INSTAT command on using the SR command to read the status bytes to determine which condition caused the error.

# INA

## Example

[XEQ] [ALPHA] INA [ALPHA]

## Comments

The INA (INput Alpha register) command inputs data from the selected device and stores the data in the calculator's Alpha register but not in the X register.

# TRIGGER

## Example

[XEQ] [ALPHA] TRIGGER [ALPHA]

## Comments

The TRIGGER command will frequently be used in conjunction with the TO Advanced Command. Consider the following program:

```
01    LBL "TRIG"          10    TRIGGER
02    AUTOIO              11    2.009001
03    CF 17               12    STO 01
04    "HP3421A"           13 ◆  LBL "ENTER"
05    FINDID              14    IND
06    SELECT              15    PSE
07    "LS2-9:F1T0"        16    ISG 01
08    OUTA                17    GTO "ENTER"
09    PSE                 18    END
```

Line 02 sets-up the 3421A with a channel list of channels 0 through 9, and for DC voltage measurements (F1). The TO command prevents the 3421A from triggering but enables the scan through the channel list and reading storage. Therefore, when the TRIGGER command is executed, the 3421A reads each channel and stores the measurement results. The readings are input to the calculator in line 06.

**NOTE**

*With the HP-41C/CV, the TRIGGER command sets up an interface timeout that occurs in 10 seconds. If the 3421A has not completed its measurements in 10 seconds, a TRANSMIT ERROR results (for example, when storing 30 readings into the 3421A internal buffer). For this reason, we recommend that the 3421A T3 trigger command be used instead of the HP-IL TRIGGER command in order to ensure proper operation.*

# INSTAT

## Example

XEQ ALPHA INSTAT ALPHA

## Comments

The INSTAT (INput STATus) command causes the 3421A (or selected device) to output its 8-bit Status Byte. The entire eight bits are transferred to 41C/CV user flags 00 through 07. Status Byte bit 0 is placed in flag 00, bit 01 is placed in flag 01, etc. This allows testing of individual bits (flags). Also, a decimal value is placed into the X-register of the calculator. This decimal value is equal to the sum of the values of the least significant six bits that are set (a '1' or logic high).

### Status Register

The Status Register in the 3421A is used to continuously monitor six conditions within the instrument. The Status Byte is an 8-bit byte sent from the Status Register in response to the INSTAT command. The figure below illustrates the Status Register and defines each bit. The bits are set (logic 1) when the indicated condition occurs and will be cleared when the INSTAT message is received, except as noted.

| | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---|---|---|---|---|---|---|---|---|
| | Always Zero | Require Service (RQS) | Abnormal Condition See Below | Low Battery | Event Occurred | Self Test Failed | Power on Reset Occurred | Data Ready |
| Bit Value: | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

Bit 6 Bit 6 of the register will be set (a "1") when there is any one-to-one correspondence of bits in the Service Request (SRQ) Mask and the lower 6 bits of the Status Register. The bit will be cleared (a "0") when the one-to-one correspondence no longer exists or, in the case of bits 0, 1, 2, 3, and 5, with the execution of INSTAT.

Although the Require Service Message will be sent by the 3421A to the calculator when this bit is set, the 41C/CV is not capable of responding to the message. For this reason, the SRQ Mask and the Require Service Message will not be discussed further in this chapter. BASIC language controllers, see Chapter 3, are capable of responding and the SRQ mask is discussed under the topic of SPOLL. This means that the digital monitor commands MN, MH, and ML cannot be used to interrupt the 41C/CV.

# INSTAT (Cont'd)

Bit 6 Bit 6 of the register will be set (a "1") when there is any one-to-one correspondence of bits in the Service Request (SRQ) Mask and the lower 6 bits of the Status Register. The bit will be cleared (a "0") when the one-to-one correspondence no longer exists or, in the case of bits 0, 1, 2, 3, and 5, with the execution of INSTAT.

Although the Require Service Message will be sent by the 3421A to the calculator when this bit is set, the 41C/CV is not capable of responding to the message. For this reason, the SRQ Mask and the Require Service Message will not be discussed further in this chapter. BASIC language controllers, see Chapter 3, are capable of responding, and the SRQ mask is discussed under the topic of SPOLL. This means that the digital monitor commands MN, MH, and ML cannot be used to interrupt the 41C/CV.

Bit 5 This bit will be set if any one of the following conditions are met. This bit will be cleared by the INSTAT command.

1. Hardware Error, such as an A/D converter error.

2. Calibration Error. This generally means a bad checksum was found in the calibration RAM. The calibration of the instrument is suspect.

3. Syntax Not Understood. An invalid command code was sent to the 3421A.

4. Can't Execute Syntax, e.g., the 3421A doesn't have an option board in slot 2 but was told to close a channel in that slot.

5. Low battery condition exists but an attempt was made to execute TOT, MH, ML, or MN.

6. An attempt was made to load the channel list with more than 30 channels.

7. An attempt was made to increment the channel list and trigger (T3) but the channel list was empty.

8. The 3421A was told to send its latest reading, but no reading was available.

9. The internal voltmeter received a trigger command but function F0 was asserted.

10. Self test failed.

Bit 4 This bit indicates a low battery condition. The bit will be cleared only when the 3421A is switched off and back on. This bit is not maskable with the SRQ mask.

# INSTAT (Cont'd)

Bit 3 Bit 3 indicates that an event has occurred as sensed by either of the three monitor functions; MN, ML, MH. Bit 3 is automatically enabled by the MH and MI commands and is cleared by the INSTAT command. The MN, ML, and MH commands are described in chapter 6.

Bit 2 This bit indicates a failure in the 3421A self test. Note that it is not maskable (see the M command). Refer to Chapter 2 for more information on Self Test.

Bit 1 Bit 1 will be set whenever a power-on reset has occurred. The bit will be cleared when the INSTAT command is sent to the 3421A. Although this bit may be true, an SRQ is not generated unless it is enabled by the Power ON SRQ switch on the rear panel.

Bit 0 When set to a "1", this bit can show that the 3421A has taken a reading (voltmeter, counter, bit, etc.) and is waiting to output it to the calculator. The following commands will set the data ready bit: DCV, ACV, TWO, FWO, FRQ, TEM, REF, TOT, RED, BIT, T1, T2, T3, DT, MH, ML, MN, and GET. This bit will be cleared if the reading is sent to the calculator (IND command) or the reading is no longer available.

Let's look at two examples of how INSTAT may be used. The first of these examples will be used in later programs.

## Example 1. Data Ready

The data ready bit (bit 0 in the Status Register) of the 3421A allows the calculator to determine when new measurement data is ready. Since the data ready bit is bit 0, it will be placed into the calculator's Flag 00 when the INSTAT command is executed. Therefore, we can test Flag 00 to see if data is ready.

# INSTAT (Cont'd)

| Keystrokes | Comments | 41C/CV Display |
|---|---|---|
| [ALPHA] DCV12 [ALPHA] | Instructions for a DC voltage reading on channel 12 | DCV12 |
| [XEQ] [ALPHA] OUTA [ALPHA] | Output the instruction to the 3421A. | |
| [XEQ] [ALPHA] INSTAT [ALPHA] | Bit 0 is set indicating data is ready. The value of this bit is '1'. | 1.0000 |
| [FS?] 00 | The test to see if Flag 00 is set returns a YES answer. | YES |
| [XEQ] [ALPHA] IND [ALPHA] | The display will show the 3421A reading. | (measured reading) |
| [XEQ] [ALPHA] INSTAT [ALPHA] | The data is no longer available. It was read into the calculator by IND. Bit 0 is cleared and INSTAT returns a '0'. | 0.0000 |
| [FS?] 00 | The Flag 00 test now shows that bit 0 in the Status Register is clear. | NO |

The DCV12 command caused the 3421A to take one reading. When the first INSTAT command was executed, the calculator display showed a "1". This is because bit 0 in the Status Register was set due to the reading being ready. When Flag 00 was tested (FS? 00), it was set and the calculator displayed "YES".

With the IND command , the measurement was sent to the calculator and no new measurements were taken. Therefore, no new readings became available and bit 0 in the Status Register is clear. This is evident by the second INSTAT command returning a "0" and the Flag 00 test answering NO.

# INSTAT (Cont'd)

The FS? and FC? tests may be used in programs to branch to subroutines if data is or is not ready.

Please note that the value returned after the first INSTAT command may be 3. This would indicate that a power-on reset of the 3421A has occurred; see Bit 2 in the Status Register. This bit will be cleared with the INSTAT command. Therefore, running through the example again should produce the results shown.

## Example 2. Abnormal Condition

As stated earlier, there are several things that can cause an error. One example of an error condition is when the 3421A receives a command that it doesn't understand or cannot comply with. The following program shows how the INSTAT command and flag tests may be used in a program to detect errors.

```
01*LBL "FLAG"
02*LBL 01
03 "DCV12"
04 OUTA
05 INSTAT
06 FS? 05
07 TONE 5
08 FS? 00
09 IND
10 GTO 01
11 END
```

Line 3 should be changed to reflect some channel that you do have in your 3421A. If an error does occur, bit 5 in the Status Register will be true. When Flag 05 is tested the tone will sound. If the bit were not true (no error), the program would skip over the TONE 5 instruction. Try it by replacing line 3 with the command DCV35. This would cause an syntax error.

To find out exactly what caused the error, execute the SR command followed by four IND commands. SR is the command to send the Status Byte plus the three error registers. Execute the following instructions.

# INSTAT (Cont'd)

| Keystrokes | Comments | 41C/CV Display |
|---|---|---|
| [ALPHA] DCV35 [ALPHA] | A DC Voltage measurement on channel 35 is illegal. An error will occur. | |
| [XEQ] [ALPHA] OUTA [ALPHA] | Output the command DCV35 | |
| [ALPHA] SR [ALPHA] | SR is the Status Register command. | |
| [XEQ] [ALPHA] OUTA [ALPHA] | Output the command SR | |
| [XEQ] [ALPHA] IND [ALPHA] | Input the first register which is the same as the Status Byte The Status Byte will will be cleared after this. The value 32 (bit 5) means an abnormal condition. | 32 |
| [XEQ] [ALPHA] IND [ALPHA] | Input the second Register which is the error register. The value 4 (bit 2) means invalid syntax. | 4 |
| [XEQ] [ALPHA] IND [ALPHA] | Input the third Register which is the hardware error register. The value 0 indicates no hardware error. | 0 |
| [XEQ] [ALPHA] IND [ALPHA] | Input the fourth Register which is the calibration error register. The value 0 means no calibration error. | 0 |

# INSTAT (Cont'd)

The four error registers will be cleared after all four have been read by the IND command. The following chart shows the meaning of each bit in the registers and its value. Remember that the decimal value returned is the sum of the values of the individual bits that are set within that register. There are actually 24 registers that can be read with the SR command, the remaining 20 are 3421A status registers. These can be used to report what option assemblies are available in the 3421A, which channels are closed, the setting of the SRQ, XOR, and AND masks, etc. Refer to the blue pages at the end of the preceeding chapter.

| Register | Bit Number | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 1 Status Register | Always 0 | SRQ | Abnormal Condition | Low Battery | Event Occurred | Self Test Error | Power on Reset | Data Ready |
| 2 Error Register | * | Tried to load channel list with more than 30 channels | Channel list is empty but tried to execute a T3 | Battery is low but tried to do TOT,MN, MH, ML | Wrong type of option for command | Invalid Syntax | No Data ready but Addressed to talk | Func F0 asserted but triggered |
| 3 Hardware Error | 10 MB test failed | RAM Error | RAM Error | uP RAM Error | A/D Error | ROM 0 Error | ROM 1 Error | Cal. RAM Check sum Error |
| 4 Cal Error | * | A/D Error | CAL RAM Bad | CAL attempted but not enabled | Invalid CAL Zero | Invalid CAL Signal | Invalid CAL Number | Invalid CAL Function or Range |
| Bit Value | 128 | 64 | 32 | 16 | 8 | 4 | 2 | 1 |

* These bits are undefined and may be either a 1 or a 0.

# PWRDN
# (POWER-DOWN)

## Example

[XEQ] [ALPHA] PWRDN [ALPHA]

## Comments

The Power-down command is used to put the 3421A and all other devices capable of power-down into their lowest, standby power condition. When the 3421A receives this command, it first stores its channel status in RAM before powering down. All multiplexer and actuator channels remain in the state they were in before the PWRDN command was received. All digital output ports are returned to a high impedance (switch opened) state. Also, the totalize mode is turned off.

The channel status information that is stored in RAM is used to remember which slots had 44462A multiplexer assemblies or 44465A Digital I/O assemblies. The status information also remembers which channels were actuators and which were multiplexers. During power-up, the 3421A will check to determine if any of this information has changed. If not, the 3421A will go to its turn on conditions. If something has changed, such as reconfiguring an actuator to a multiplexer channel, etc., the 3421A will go through its self test and reset state.

The 3421A will return to its full power-on state when there is any communication through the HP-IL interface. Refer to the PWRUP command for more information on power-up.

**SPECIAL NOTE ON LOW BATTERY.** Since the 3421A is a battery powered instrument, certain safeguards have been included to prolong the life of the battery. When the battery voltage drops below a predetermined point, the 3421A sets bits 6, 5, and 4 in the Status Byte (see INSTAT). The error indicator also lights up on the display. After approximately three minutes the 3421A will open all relays and power down. The Power-up (PWRUP) command will not cause the 3421A to power-up. The 3421A LINE switch must be cycled and the battery must be charged.

**SPECIAL NOTE TO OPTION 040, 44464A BREADBOARD ASSEMBLY USERS.** During power down, the breadboard assembly will lose all power supplies. Therefore, you may want to use latching relays if you need a relay closed during power-down.

# PWRUP
# (POWER-UP)

## Example

[XEQ] [ALPHA] PWRUP [ALPHA]

## Comments

The PWRUP command is used to return all powered-down instruments to their full operating power conditions. Actually, the 3421A will return to normal operation when there is any communication through the HP-IL interface. When the 3421A powers-up, it first checks its status to see if any multiplexer boards were changed. If any changes have been made, the 3421A will go through its normal power-on reset and self test routine. If nothing has been changed, the 3421A remains in the same state that it was in prior to power-down. That is to say that all multiplexer or actuator relays that were closed prior to power-down will remain closed after power-up. Note that the power up command has no effect on instruments manually turned off.

# FINDID

## Example

[ALPHA] HP3421A [ALPHA]

[XEQ] [ALPHA] FINDID [ALPHA]

## Comments

The FINDID (**FIND** IDentity) command searches for a device with a specific identity and returns with the HP-IL address of that device. The device identity must be placed in the Alpha register of the calculator before FINDID is executed. The identity of the 3421A is: HP3421A. The address is returned to the X-register of the calculator.

In the AUTOIO mode the calculator searches the entire loop starting at the "selected" device. In the MANIO mode, the calculator checks only the "selected" device for the identity.

What happens if there are two or more 3421A's in the loop? If the interface is in the AUTOIO mode when FINDID is executed, the address of the first 3421A (starting with the selected device) is returned and the search ends. If we then "select" the device after the first 3421A (next address) and execute FINDID again. The calculator will return the address of the second 3421A. By selecting the device after the 3421A, we can find the address of the next 3421A.

# AUTOIO

## Example

[XEQ] [ALPHA] AUTOIO [ALPHA]

## Comments

The 82160A HP-IL interface module for the calculator controls the interface loop according to the module's operating mode—either Auto or Manual. The AUTOIO mode is the easiest to use with all HP-IL devices including the 3421A. This is especially true if you have a printer and/or cassette drive in the loop.

In the AUTOIO (**AUTO** I/O) mode, when you execute a printer or cassette drive operation, the interface automatically searches through the loop for the proper device to carry out the operation. Hence the name AUTOIO. For example, if you execute the PRA (PRint Alpha register) command when the 3421A is the selected device, the printer in the loop automatically performs the operation. In the Manual mode, the printer would have to be selected before the PRA command could be executed.

# MANIO

## Example

[XEQ] [ALPHA] MANIO [ALPHA]

## Comments

The MANIO (**MAN**ual I/O) mode, means that device such as printers and cassette drives, must be "selected" before used. When MANIO is asserted, flag 32 is set in the 41C/CV calculator showing that the interface is in the MANIO mode.

# REMOTE

## Example

[XEQ] [ALPHA] REMOTE [ALPHA]

## Comments

The REMOTE command is used to cause the selected device to switch from local front panel control to remote program control. The remote mode of the 3421A is always asserted since it does not have a keyboard front panel. For this reason, it is not necessary to execute the REMOTE command if the 3421A is the only device in the loop. The 3421A ignores the REMOTE command.

# LOCAL

## Example

[XEQ] [ALPHA] LOCAL [ALPHA]

## Comments

The LOCAL command is used to clear the selected device from the Remote mode and restore front panel operation. Since the 3421A does not have a front panel keyboard for control and must remain in the Remote mode, the LOCAL command is ignored.

# LISTEN

## Example

[XEQ] [ALPHA] LISTEN [ALPHA]

## Comments

The LISTEN command makes the selected device a dedicated listener, that is, the device is enabled to recieve information. A number must be placed into the X-register, representing the address of the selected device, prior to executing the LISTEN command. The address in the X-register should be between 1 and 30. However, if the number is 31 and the LISTEN command is executed, all devices in the loop are removed from the Listen mode.

This command allows more than one listener to be setup by executing the LISTEN command for each device. For example, suppose you have two 3421A's in the loop. You need them to trigger simultaneously. Individually, both instruments should be made listeners. When the TRIGGER command is executed, both voltmeters are triggered almost simultaneously. The time differential is the time required for the TRIGGER message to travel from one device to the next. The alternative is to select and trigger each voltmeter individually.

# SAMPLE APPLICATION PROGRAMS

## Writing Programs

Earlier in this chapter we looked at a simple ac voltage measurement and developed a simple program for the 41C/CV calculator. That program illustrates the essentials of programming, namely; 1. a Label, 2. setting up the 3421A for the particular measurement(s), 3. triggering or executing the command, and 4. inputting the results. Of course, the program must also have an END statement. For more specific information on programming the 41C/CV, refer to the Owner's Handbook and Programming Guide.

## Initialization

The following program locates the 3421A in the HP-IL loop (finds its address) and selects it to receive information. This is especially important if more than one device is in the loop. This program is used by the rest of the example programs in this chapter. The initialization program should be run before any other command or program is executed. This program need only be executed once unless an instrument is turned off or the loop is broken to remove or insert an instrument. The 82160A HP-IL Module should be inserted in the calculator before entering the program.

# SAMPLE APPLICATION PROGRAMS (Cont'd)

## Initialization Program

| Keystrokes | Comments | Display |
|---|---|---|
| [PRGM] | | |
| ■ [GTO] [.] [.] | | |
| ■ [LBL] [ALPHA] INI3421 [ALPHA] | INI3421 is the program name. | 01 LBL INI3421 |
| [XEQ] [ALPHA] AUTOIO [ALPHA] | Sets interface to AUTO mode. | 02 AUTOIO |
| ■ [CF] 17 | Specifies normal end-of-line operation. | 03 CF17 |
| [ALPHA] HP3421A [ALPHA] | 3421A identity. | 04 HP3421A |
| [XEQ] [ALPHA] FINDID [ALPHA] | Searches for HP3421A. | 05 FINDID |
| [XEQ] [ALPHA] SELECT [ALPHA] | Selects 3421A | 06 SELECT |
| ■ [RTN] | Returns to mainline program. | 07 RTN |
| ■ [GTO] [.] [.] | | PACKING |
| [PRGM] | | |

The initialization program has now been entered. If you have not yet connected your 3421A into the loop, do so now. Remember to turn the calculator off before connecting any instrument to the loop. The initialization program will not be lost in the calculator with power turned off.

# SAMPLE APPLICATION PROGRAMS (Cont'd)

## Running the Program

To run the initialization program, execute the following command:

[XEQ] [ALPHA] INI3421 [ALPHA]

The calculator will return with the HP-IL address of the 3421A. Now, let's go one step further and assign this program to the calculator TAN key. This will make execution easier in the future.

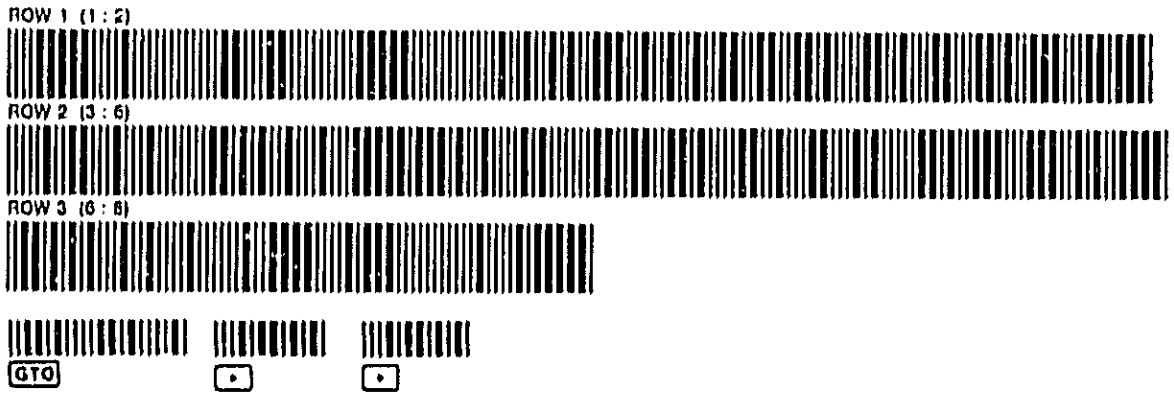
[ASN] [ALPHA] INI3421 [ALPHA] [TAN]

Now, when you want to execute the program, put the calculator in the USER mode and press the TAN key. The following is the -hp-Model 82153A Wand bar code for the initialization program.

```
01*LBL "INI3421"
02 AUTOID
03 CF 17
04 "HP3421A"
05 FINDID
06 SELECT
07 RTN
08 .END.
```

INITIALIZE

PROGRAM REGISTERS NEEDED: 5



# SAMPLE APPLICATION PROGRAMS (Cont'd)

## 3421A Front Panel

This 41C/CV program allows the calculator to serve as a remote front panel for the 3421A. The top two rows of keys and the shifted keys of the top row are defined by the program as the 15 main functions of the 3421A. The key assignments are shown in the keyboard overlay below. The functions are automatically assigned 41C/CV Local Labels A through J and a through e (shifted A through E). This is an excellent program when used to setup and test your system.

Operation of the program is simple. Load the program, either manually by the keyboard or using the -hp- 82153A Wand and Bar Code, and assign "FP" to the shifted R/S key. Make sure that all key assignments from the top two rows of keys are cleared. Put the calculator into the USER mode and press shift R/S to start the program. Remember to duplicate the keyboard overlay because many of the keys in the following examples are from the overlay.

Now if you want to make a DC Voltage measurement on channel 5, simply press: 5 [DCV]

To read the temperature on channel 9, press: 9 [TEM]

To write the value 32 to the digital I/O card in slot 1, press:

32 [ENTER↑] 1 [WRT RED]

To reset the 3421A, press: [R/S]

There are a few things to keep in mind when using this program. First, only one channel can be specified, no channel lists. Second, entries are only accepted while the 41C/CV is PAUSED. This means that the first key entry in the sequence may need to be held down until the calculator responds by displaying the key pressed. Other things to be aware of are:

1. Make certain that the INI3421 program is in the calculator.

2. Display format is fixed at ENG 5.

3. If "------" is displayed, it means no readings are available yet.

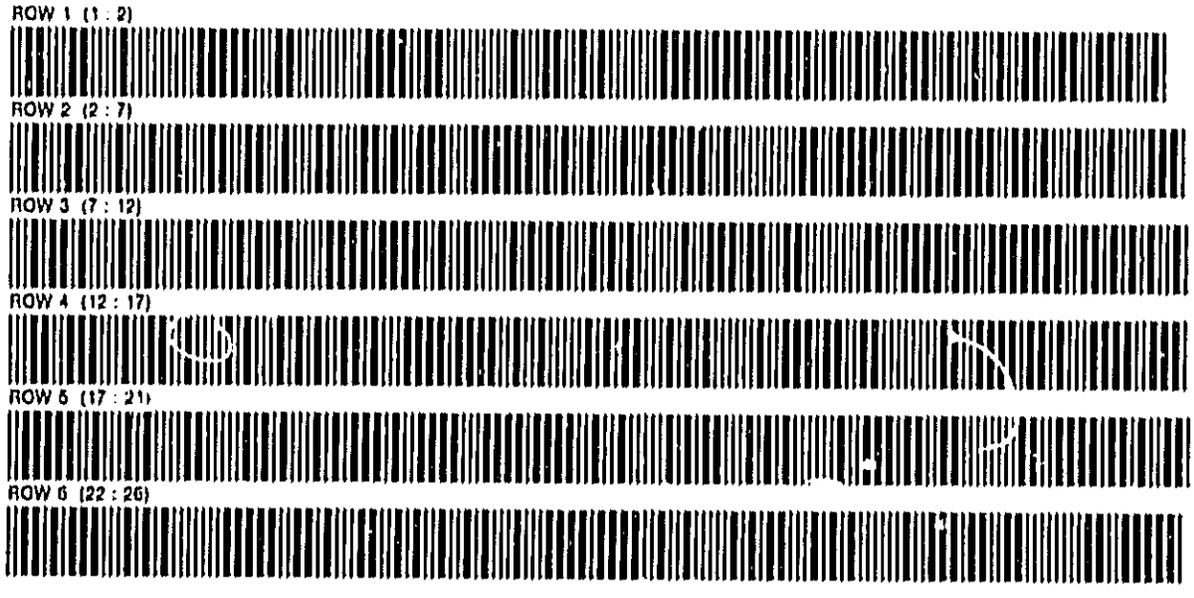
4. Repeated readings are made by the program on the channel specified. Flag 19 is used in the program to indicate repeated sending of the command and reading of data.

# SAMPLE APPLICATION PROGRAMS (Cont'd)

```
01♦LBL "FP"
02 XEQ "INI3421"
03 INSTAT
04 CF 19
05 GTO 01
06♦LBL A
07 "DCV"
08 XEQ "AX"
09 SF 19
10 GTO 02
11♦LBL B
12 "TEM"
13 XEQ "AX"
14 SF 19
15 GTO 02
16♦LBL C
17 "TWO"
18 XEQ "AX"
19 SF 19
20 GTO 02
21♦LBL D
22 "FRQ"
23 XEQ "AX"
24 SF 19
25 GTO 02
26♦LBL E
27 "RED"
28 XEQ "AX"
29 SF 19
30 GTO 02
31♦LBL F
32 "CLS"
33 XEQ "AX"
34 CF 19
35 GTO 02
36♦LBL G
37 "CLP"
38 XEQ "AX"
39 CF 19
40 GTO 02
41♦LBL H
42 "OPN"
43 XEQ "AX"
44 CF 19
45 GTO 02
46♦LBL I
47 "BIT"
48 XEQ "AX"
49 SF 19
50 GTO 02
51♦LBL J
52 "RS"
53 OUTA
54 CF 19
55 GTO 02
56♦LBL a
57 "ACV"
58 XEQ "AX"
59 SF 19
60 GTO 02
61♦LBL b
62 "REF"
63 XEQ "AX"
64 SF 19
65 GTO 02
66♦LBL c
67 "FWD"
68 XEQ "AX"
69 SF 19
70 GTO 02
71♦LBL d
72 "TOT"
73 XEQ "AX"
74 CF 19
75 GTO 02
76♦LBL e
77 "WRT"
78 XEQ "AY"
79 CF 19
80 GTO 02
81♦LBL 01
82 " -------"
83 AVIEW
84 SF 28
85 SF 29
86♦LBL 02
87 ENG 5
88 PSE
89 INSTAT
90 FS? 05
91 TONE 5
92 FC? 00
93 GTO 02
94 IND
95 VIEW X
96 FS? 19
97 TRIGGER
98 GTO 02
99♦LBL "AX"
100 FIX 0
101 CF 28
102 CF 29
103 FS?C 22
104 ARCL X
105 OUTA
106 RTN
107♦LBL "AY"
108 FIX 0
109 CF 28
110 CF 29
111 ARCL X
112 "+"
113 ARCL Y
114 OUTA
115 RTN
116 .END.
```

FRONT PANEL

PROGRAM REGISTERS NEEDED: 46



ROW 7 (26 : 30)

ROW 8 (31 : 35)

ROW 9 (35 . 39)

ROW 10 (40 : 44)

ROW 11 (44 : 48)

ROW 12 (49 : 54)

ROW 13 (55 : 59)

ROW 14 (59 : 63)

ROW 15 (64 : 68)

ROW 16 (68 : 73)

ROW 17 (73 : 78)

ROW 18 (78 : 82)

ROW 19 (82 : 89)

ROW 20 (89 : 95)

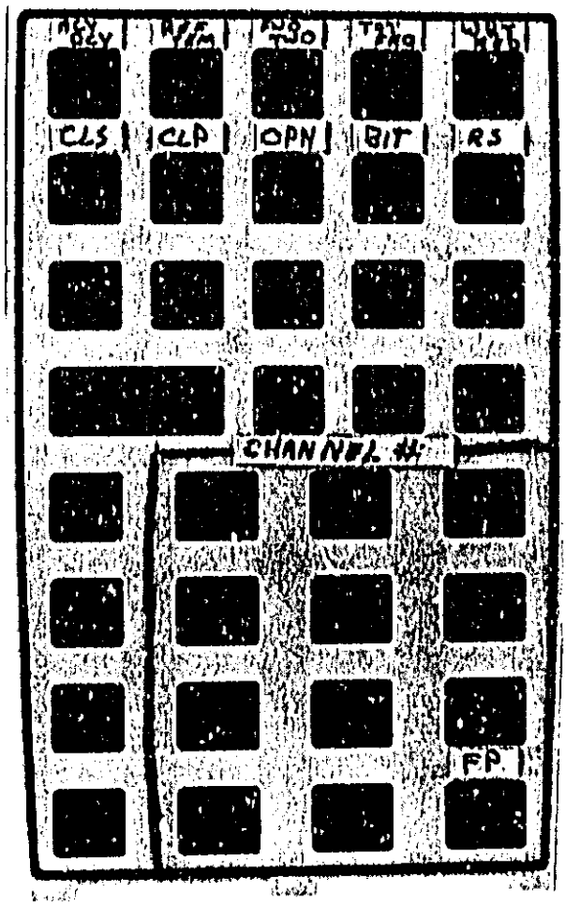
ROW 21 (95 : 100)

ROW 22 (100 : 107)

ROW 23 (107 : 111)

ROW 24 (112 : 116)

GTO




## Sample Programs

The following three examples illustrate program writing with the -hp- 41C/CV. They also demonstrate the flexibility and programming power of the 3421A and 41C/CV combination. All three programs use the Initialization Program to set up the 3421A. In addition to the program listings, bar codes are also provided for use with the -hp- 82153A Wand.

Remember that these programs, or any programs, can be assigned to individual keys in the calculator. Also, with simple modifications, the programs can be incorporated as subprograms into other mainline programs.

# TEMPERATURE MEASUREMENTS
## (using a thermistor)

The thermistor temperature program computes the temperature, in degrees C, corresponding to the resistance of a thermistor. The program has been designed to work with thermistors exhibiting a 5.000 kOhm resistance at 25°C, such as a type 44007 (-hp- part number 0837-0164) or equivalent.

The program was written for a 2-wire resistance measurement on the specified channel. This will provide accurate results in most cases. For greater accuracy at high temperatures, a 4-wire resistance measurement should be made. Change line 06 to read "FWO". This program is useful over a range of -80°C to +150°C.

The equation used to convert the measured resistance to a temperature is:

$$\text{Temperature} = \frac{1}{A + B(\text{LOG}(R)) + C(\text{LOG}(R))^3} - 273.15$$

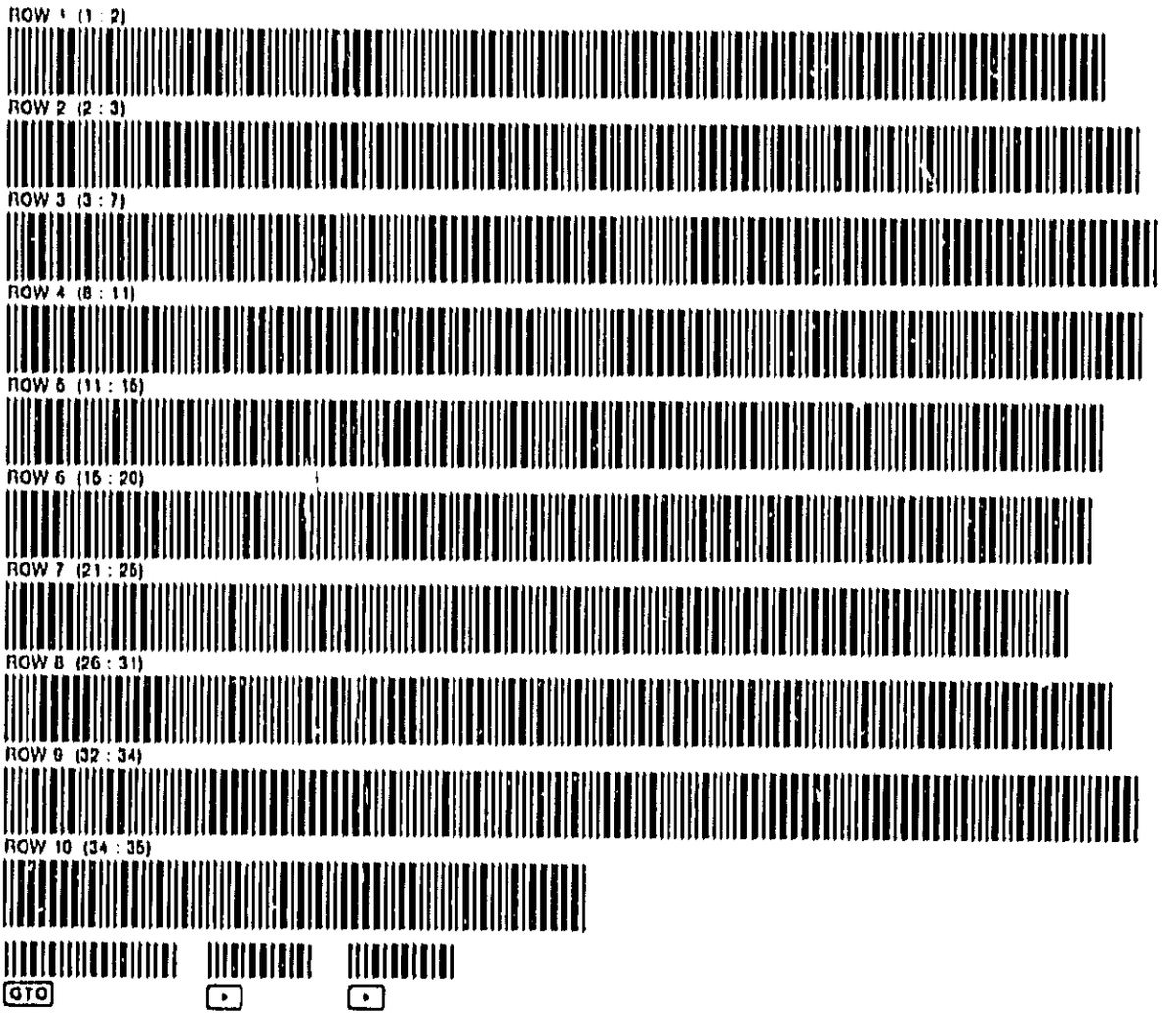
where R is the measured resistance and A, B, and C are the conversion coefficients found in lines 24, 20, and 15, respectively. To use this program with a 2252 Ohm thermistor (25°C) change the coefficients to: 1.4709 E-3 (line 24), 2.3779 E-4 (line 20), and 1.0326 E-7 (line 15).

```
01*LBL "THERMIS"
02 XEQ "IHI3421"
03 "CHANNEL ?"
04 PROMPT
05 FIX 0
06 "TWO"
07 "+"
08 ARCL X
09 OUTA
10*LBL "MEAS"
11 TRIGGER
12 IND
13 LN
14 STO 00
15 9.3244 E-8
16 RCL 00
17 3
18 Y↑X
19 *
20 2.361 E-4
21 RCL 00
22 *
23 +
24 1.2855 E-3
25 +
26 1/X
27 273.15
28 -
29 FIX 2
30 CLA
31 ARCL X
32 "+ DEG C"
33 AVIEW
34 GTO "MEAS"
35 .END.
```

# TEMPERATURE MEASUREMENTS (Cont'd)

THERMISTOR

PROGRAM REGISTERS NEEDED: 18



# TEMPERATURE MEASUREMENTS
# (using thermocouples)

There are two versions of the thermocouple temperature program. The first assumes that only type T thermocouples are used. Since the 3421A already has the conversion coefficients designed into it for type T thermocouples, this makes the programming task much easier.

The program is labeled TTEMP. It will prompt you for a channel number and then proceed to measure the thermocouple and display the temperature (in degrees C) on the calculator display.

The second version allows type J, E, K, R and S thermocouples. The program, THERMO was written for J type thermocouples. If you will be using other types of thermocouples, the coefficients in lines 17, 19, 27, 29, 32, 35, 38, 41, 44, 47, 50, and 53 must be changed as per the table below.

Lines 11 through 23 provide the software compensation for the reference junction temperature. The equation for the compensation voltage is: $V = P0 + T*(P1 + (T*P2))$. In this equation, T is the measured reference temperature and $V_c$ is the compensation voltage. This voltage is added to the measured thermocouple voltage $V_t$ (line 23) to compensate for the reference junction. Lines 24 through 54 in the program convert this compensated voltage ($V_c$ + $V_t$) to a temperature in degrees C. The equation used is a ninth order polynomial of the form:

$$\text{Temperature} = P0 + VP1 + V^2P2 + V^3P3 + \ldots + V^9P9.$$

Here, V is the compensated voltage and P0 through P9 are the conversion coefficients.

## Thermocouple Type

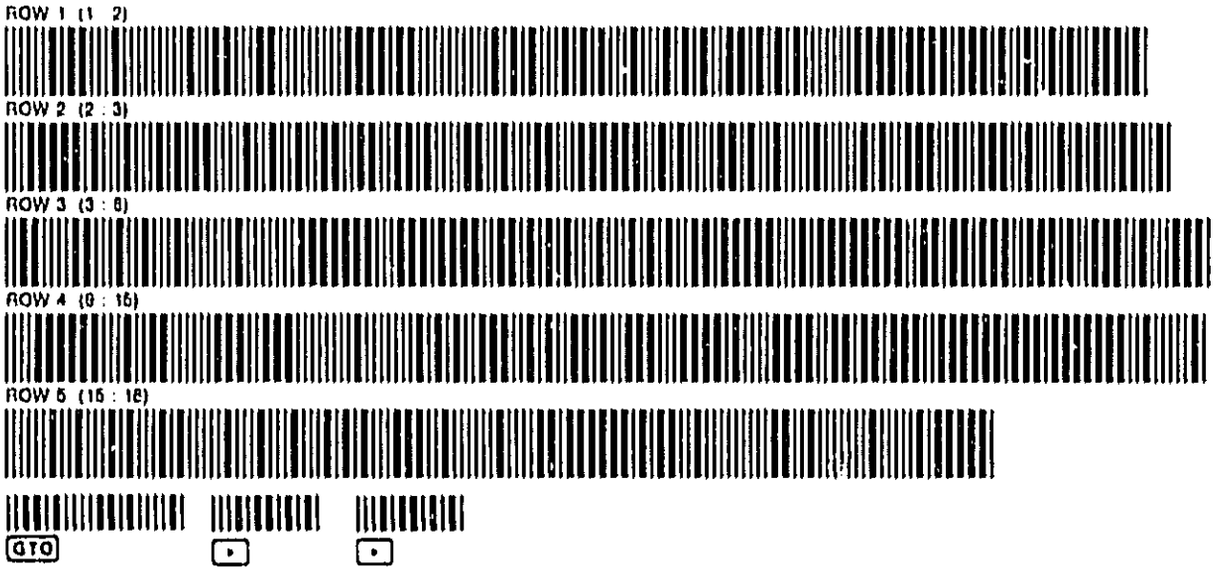
| Line Number | J | E | R | K | S |
|---|---|---|---|---|---|
| 17 | 2.3E 8 | 4.6E 8 | 1.2E 8 | 1.6E 8 | 1.1E 8 |
| 19 | 6.053E 6 | 6.866E 5 | 6.334E 6 | 3.964E 5 | 6.442E 6 |
| 27 | 3.0840254E16 | 1.2777466E15 | 1.9280744E18 | 1.3828614E16 | 8.2663728E18 |
| 29 | 5.3718266E15 | 4.1055296E14 | 2.9235605E18 | 3.3991028E15 | 2.8874849E18 |
| 32 | 3.79243843E14 | 5.3981272E13 | 1.7414496E17 | 3.4782347E14 | 2.0689294E17 |
| 35 | 1.38014121E13 | 3.7221944E12 | 5.4842602E16 | 1.9109E13 | 6.79267949E15 |
| 38 | 2.7150638E11 | 1.4284868E11 | 1.01396299E12 | 6.0392865E11 | 1.2361123E14 |
| 41 | 2.831128E9 | 2.8690242E9 | 1.13982593E12 | 1.0820624E10 | 1.327040E12 |
| 44 | 1.821297E7 | 3.049432E7 | 7.787787E9 | 9.9661057E7 | 8.477335E9 |
| 47 | 1.75117E6 | 2.05411E6 | 3.27669E7 | 3.82662E6 | 3.26257E7 |
| 50 | 1.97609E4 | 1.61293E4 | 1.726466E6 | 2.48503E4 | 1.73545E6 |
| 53 | 3.6E1 | 2.1E 1 | 1.5E0 | 5.1E 2 | 1.4E0 |

# 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 3.0840254 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 1.97589 E4
51 +
52 *
53 -3.6 E-1
54 +
55 ARCL X
56 "⊢ DEG C"
57 AVIEW
58 .END.
```

## THERMO COUPLE

## PROGRAM REGISTERS NEEDED: 32

ROW 1 (1 : 2)

ROW 2 (2 : 3)

ROW 3 (3 : 6)

ROW 4 (0 : 15)

ROW 5 ( 6 : 10)

ROW 6 (10 : 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

# 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.

# DATA LOGGER (Cont'd)

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.

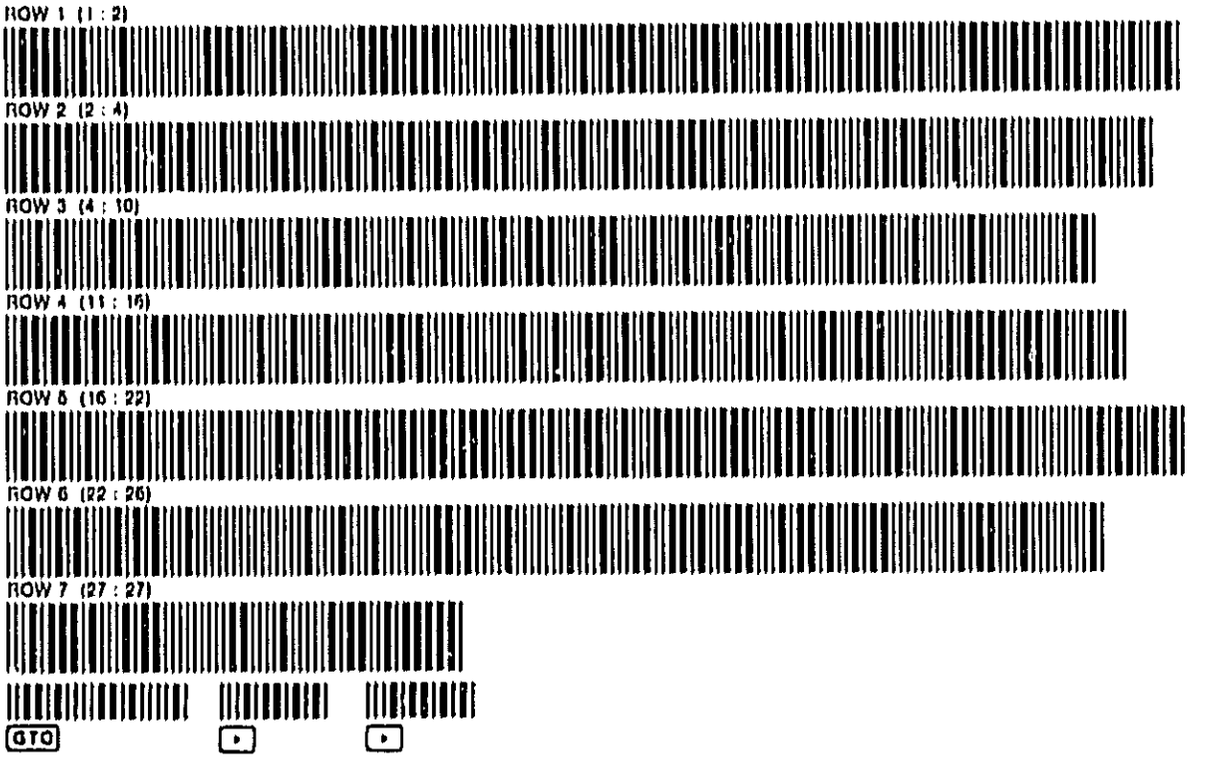
Lines 08 and 09 are used to read the measured values into registers 10 through 19. Note that these are the same registers used in the logger program to specify the channels to be measured. These particular registers are used in this program so that when the values are printed, lines 10 and 11, the printout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

# 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 OUTR
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

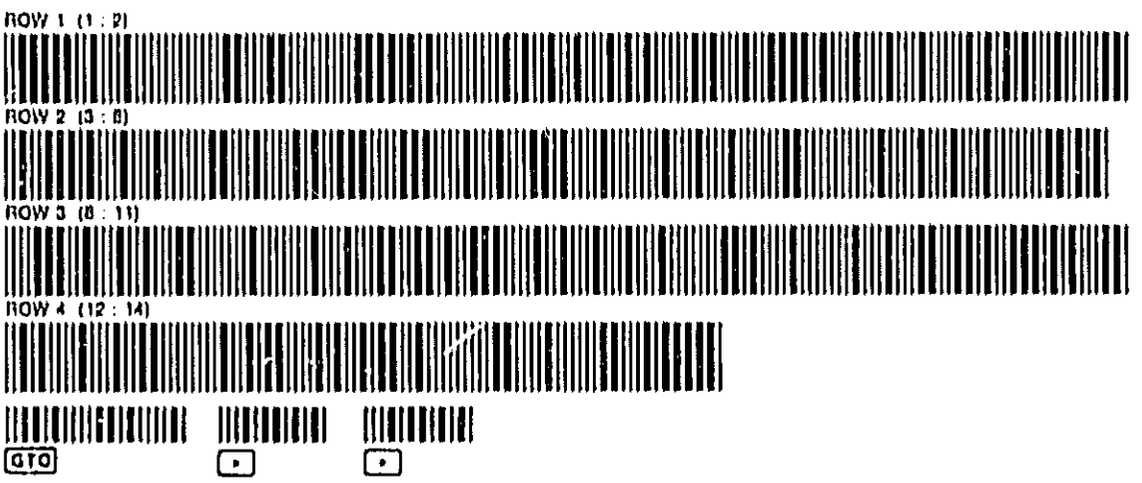


# DATA LOGGER (Cont'd)

```
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



# 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'.

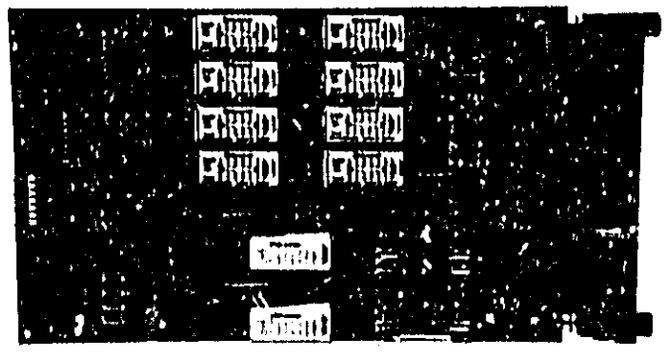
# CHAPTER 5

# 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.



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 |

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 |

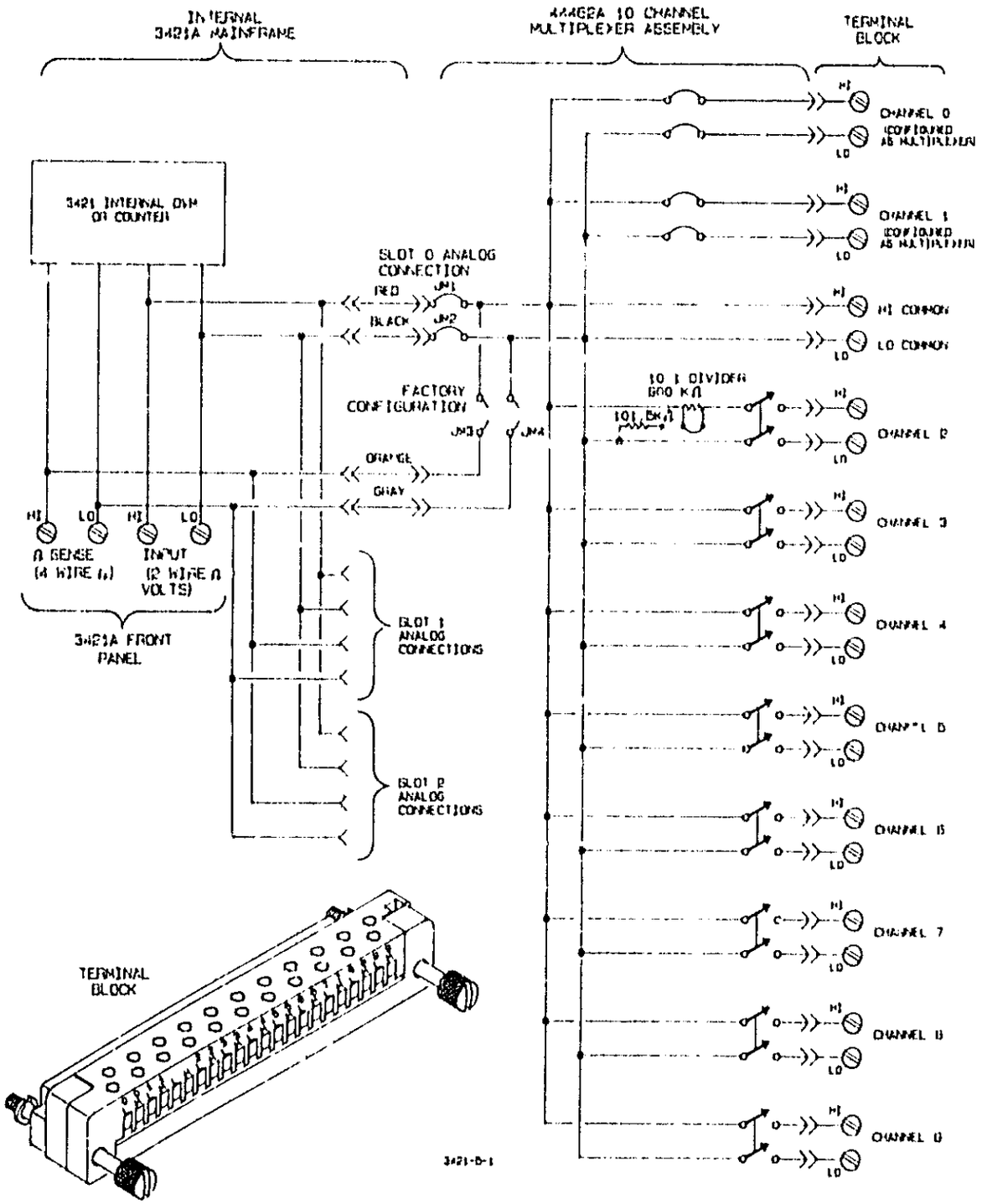



Figure 5-1. Simplified Schematic

| 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.

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.*

**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.

## 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.

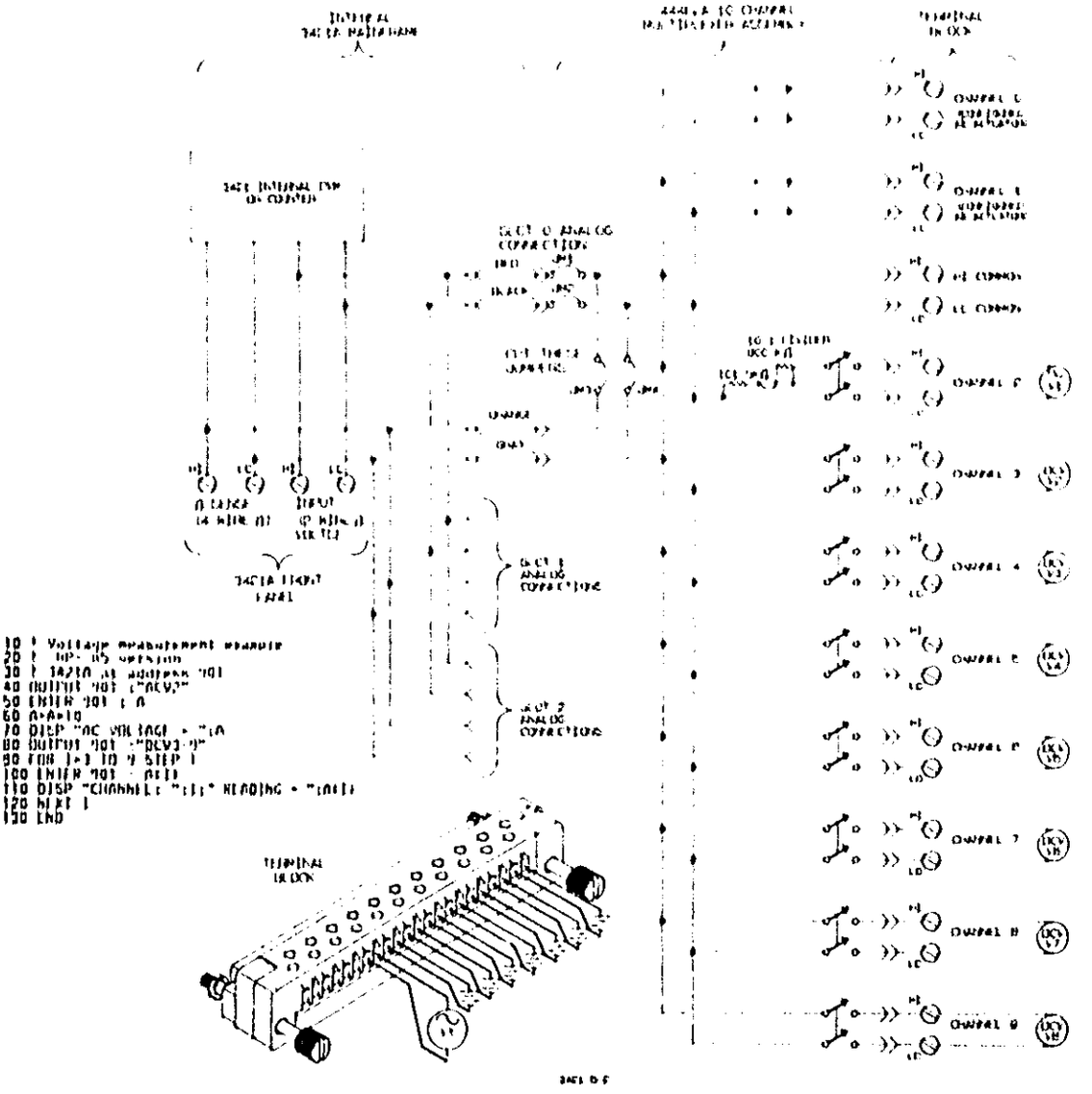



**Figure 5-2. Voltage Measurements**

# 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.

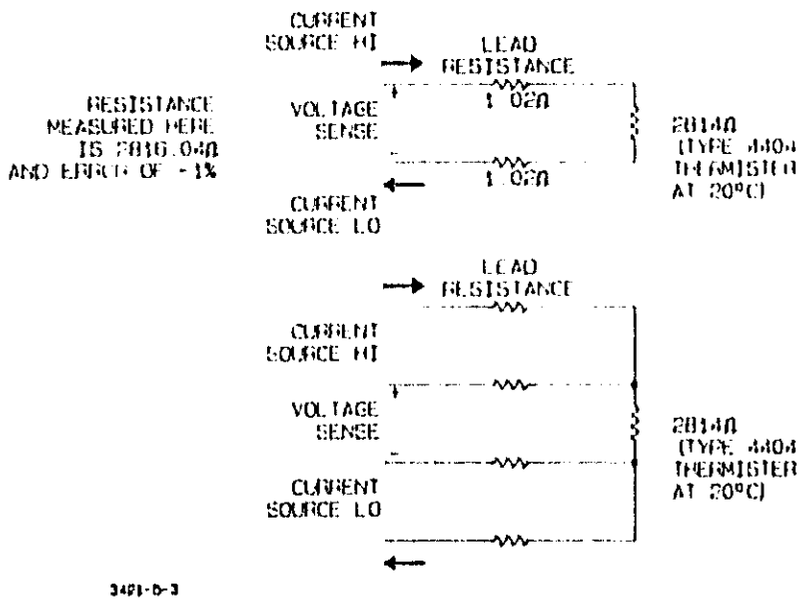



**Figure 5-3. 2-Wire vs. 4-Wire Resistance Measurements**

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.

## 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.

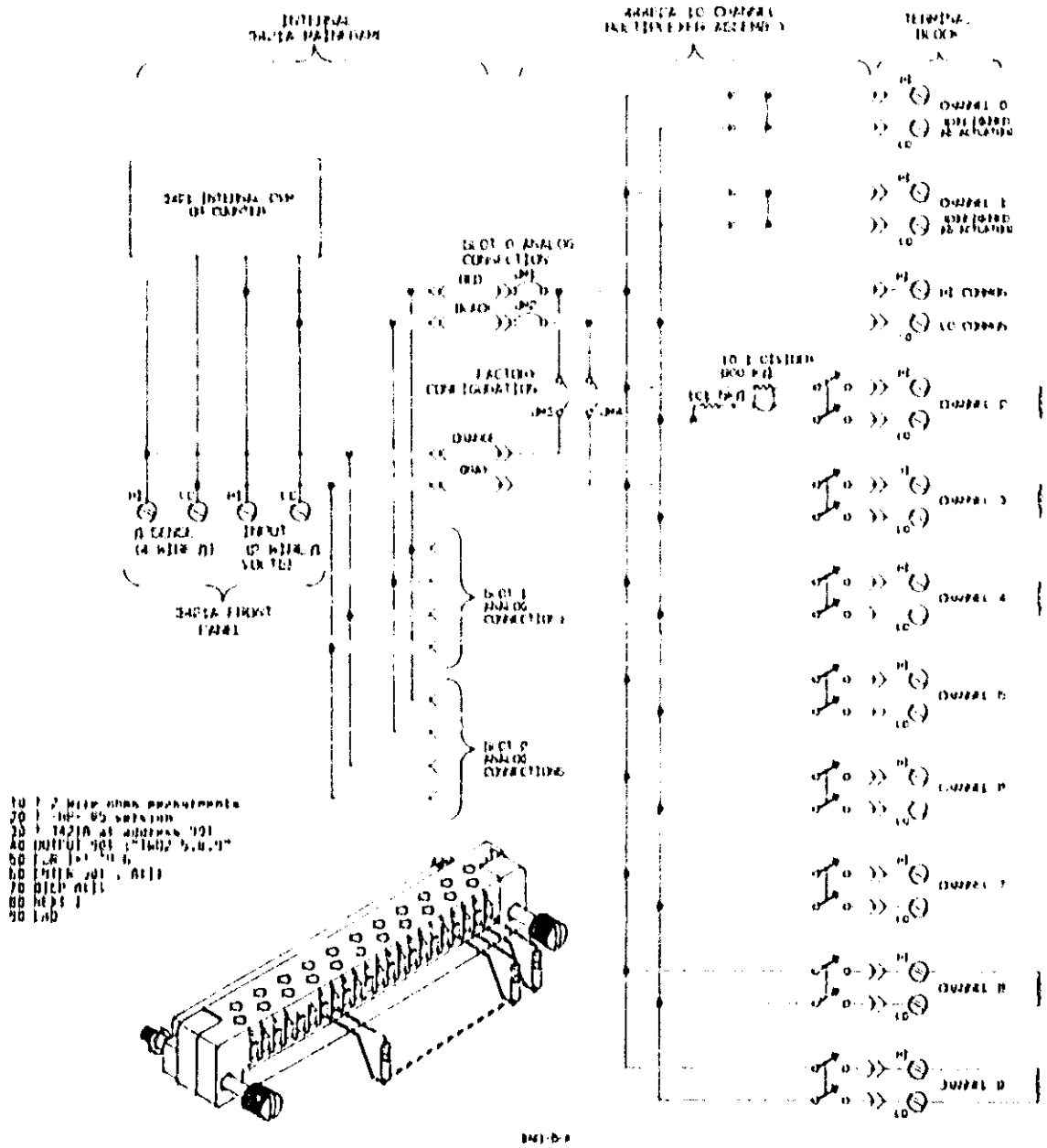


Figure 5-4. 2-Wire Resistance Measurements

## 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.

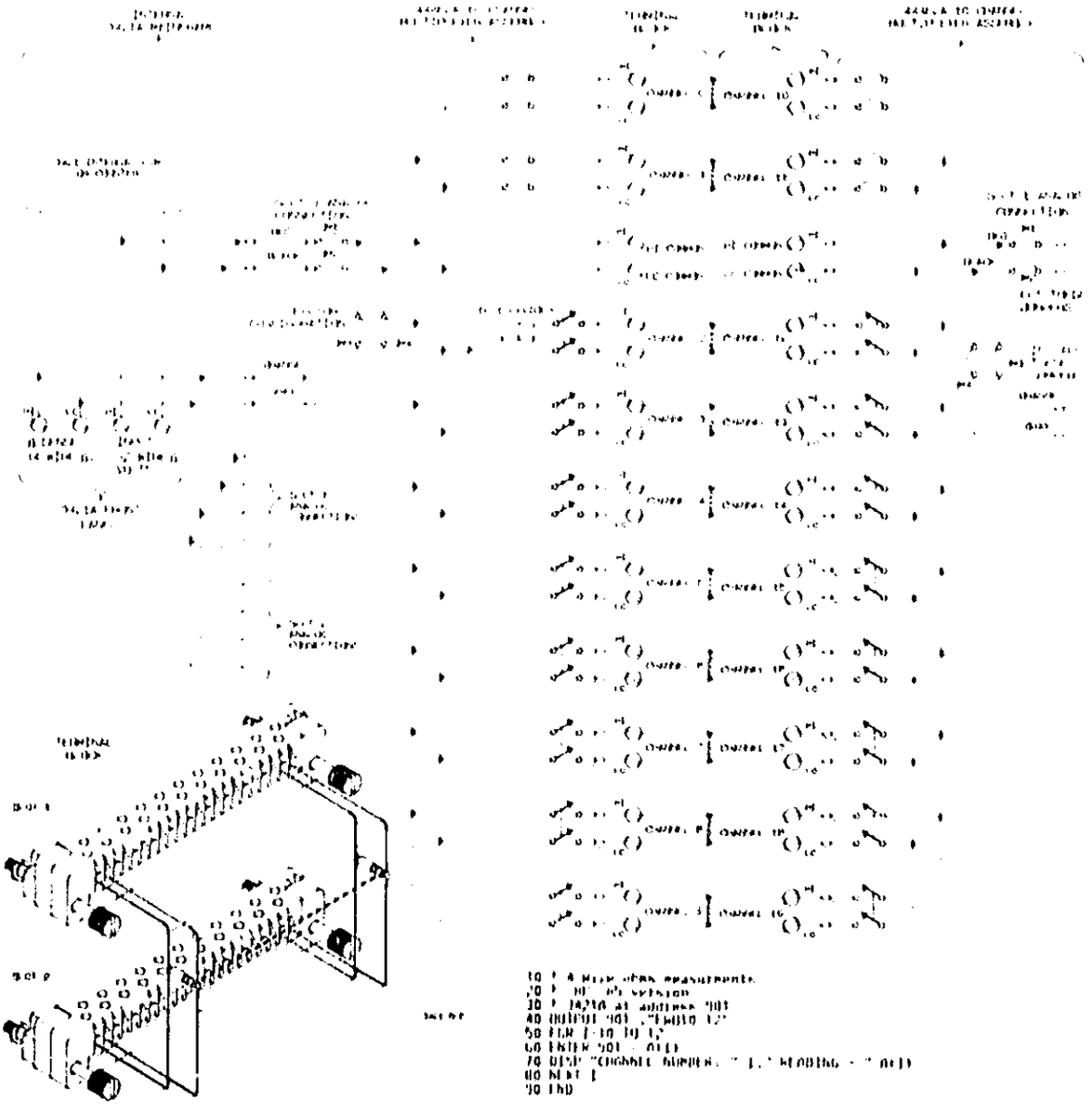


Figure 5-5. 4-Wire Resistance Measurements

# 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.

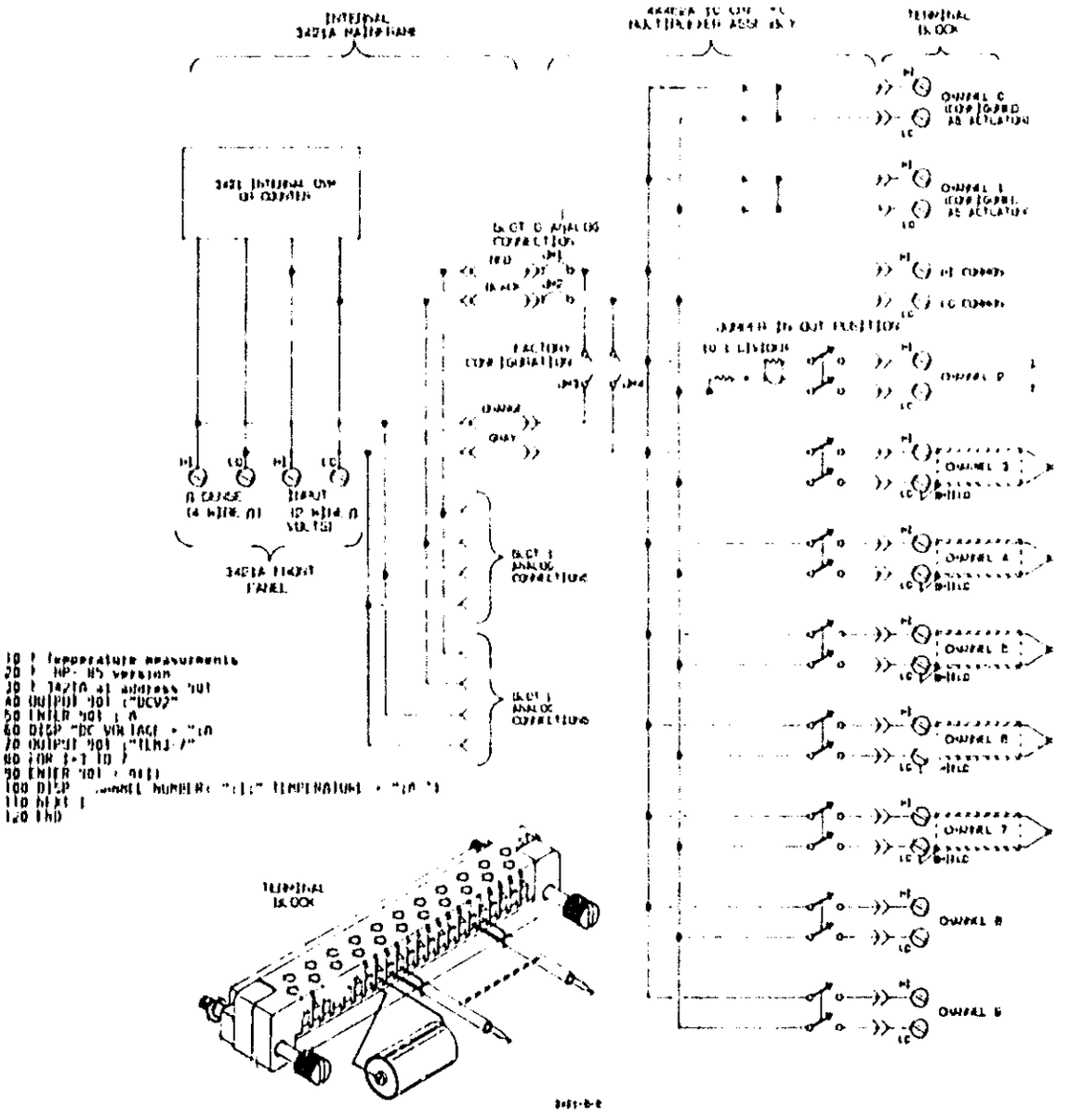


Figure 5-6. Temperature Measurements

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. One copy was provided with this manual.

# 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.

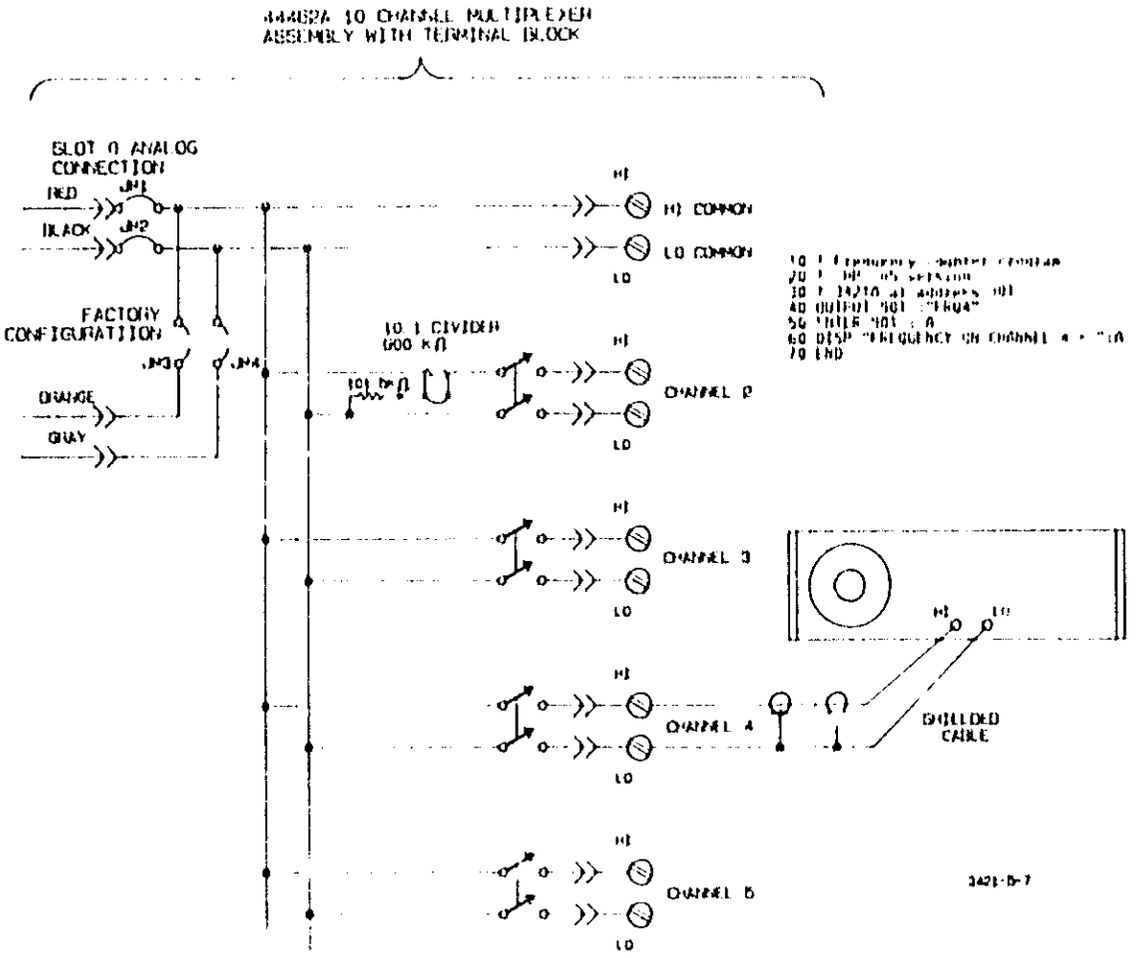


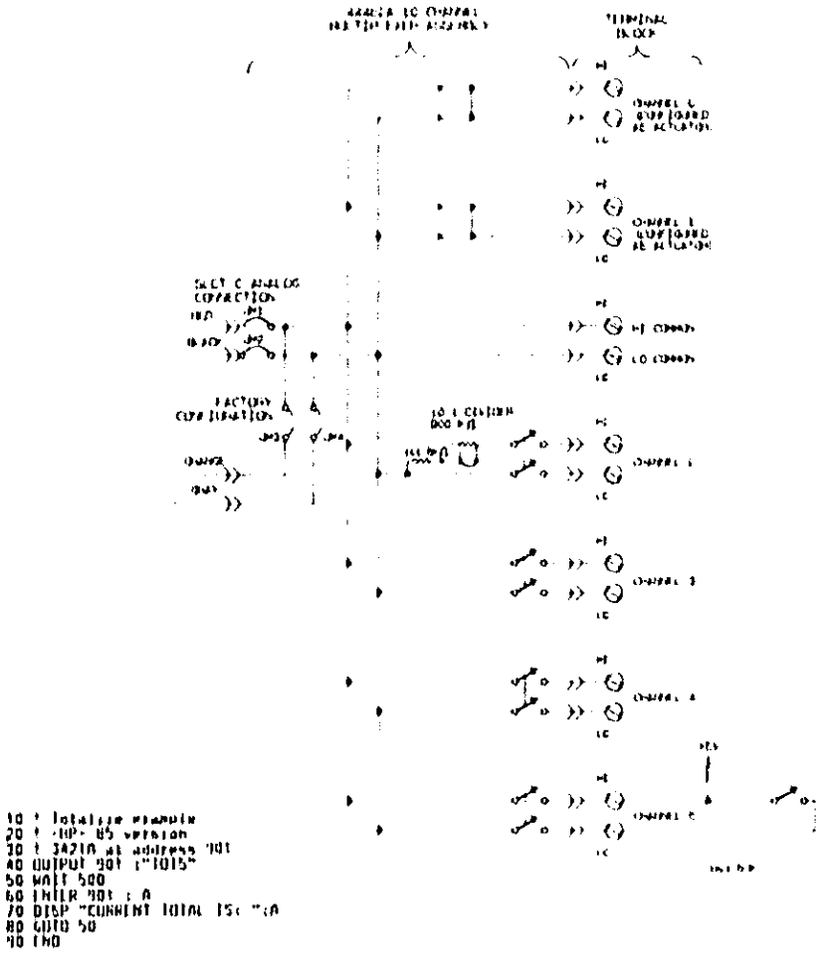

**Figure 5-7. Frequency Measurements**

## 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.



```
10 ! totalize example
20 ! <HP- 85 version
30 ! 3421A at address 701
40 OUTPUT 701 :"T015"
50 WAIT 500
60 ENTER 701 ; A
70 DISP "CURRENT TOTAL IS: ";A
80 GOTO 50
90 END
```

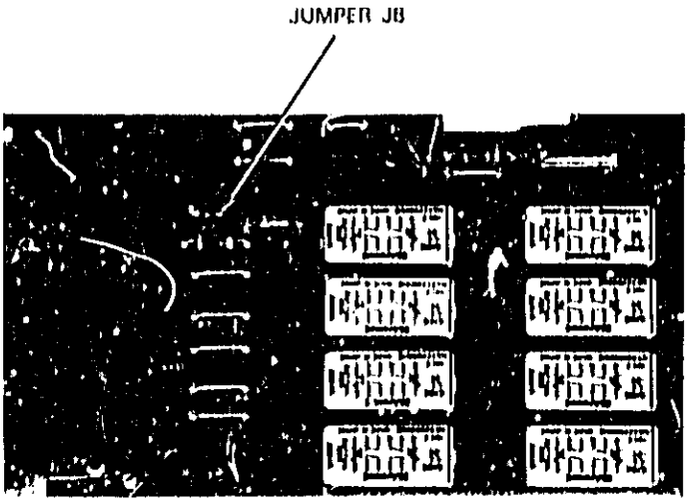
**Figure 5-8. Totalizing**

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.




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.*

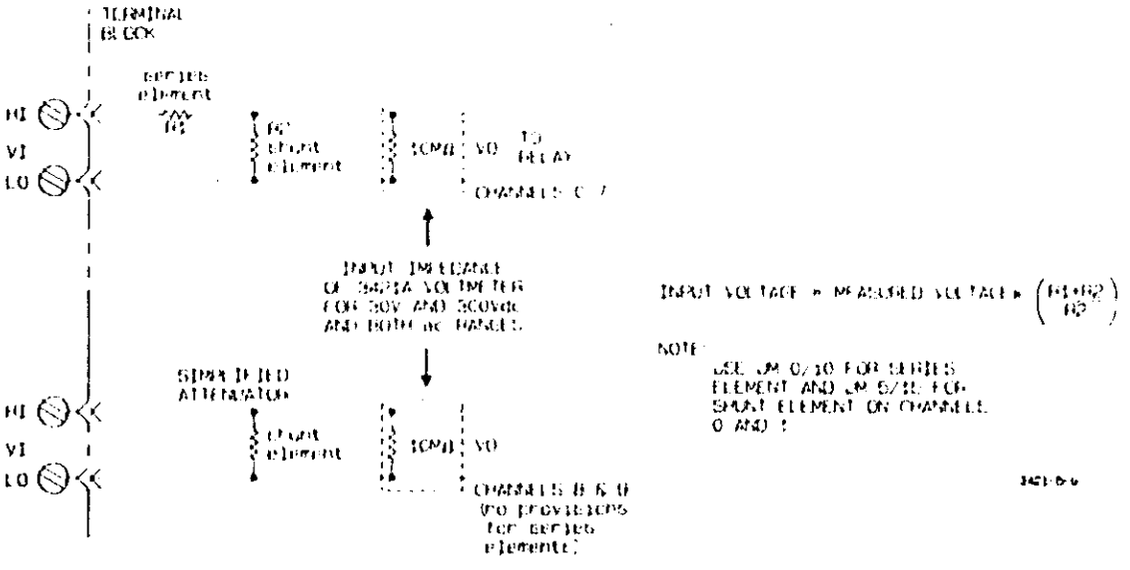



**Figure 5-8. Attenuators**

# 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.*

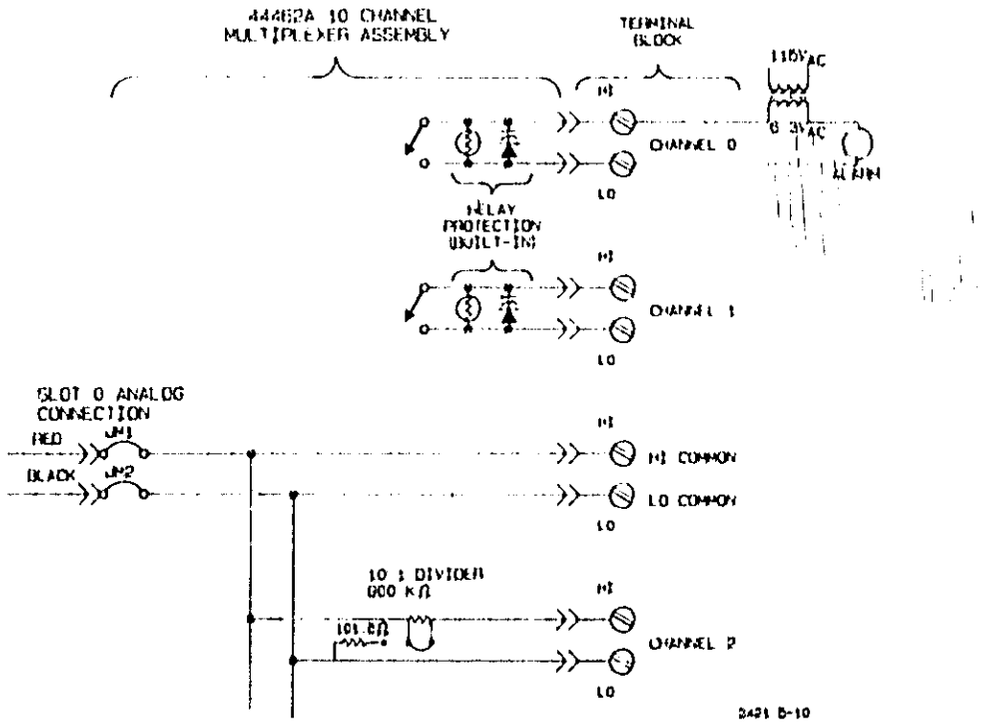



**Figure 5-10. Actuator**

## 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.

## 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.

```
10 DIM A(7)
20 OUTPUT 901 ;"LS2-7,FIRMIZING
   " ! SET UP 3421A FOR
       MEASUREMENTS
30 OUTPUT 901 ;"M1" ! SET SPO
     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 8 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.*

# 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 ;"T0LS5-5;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.

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.

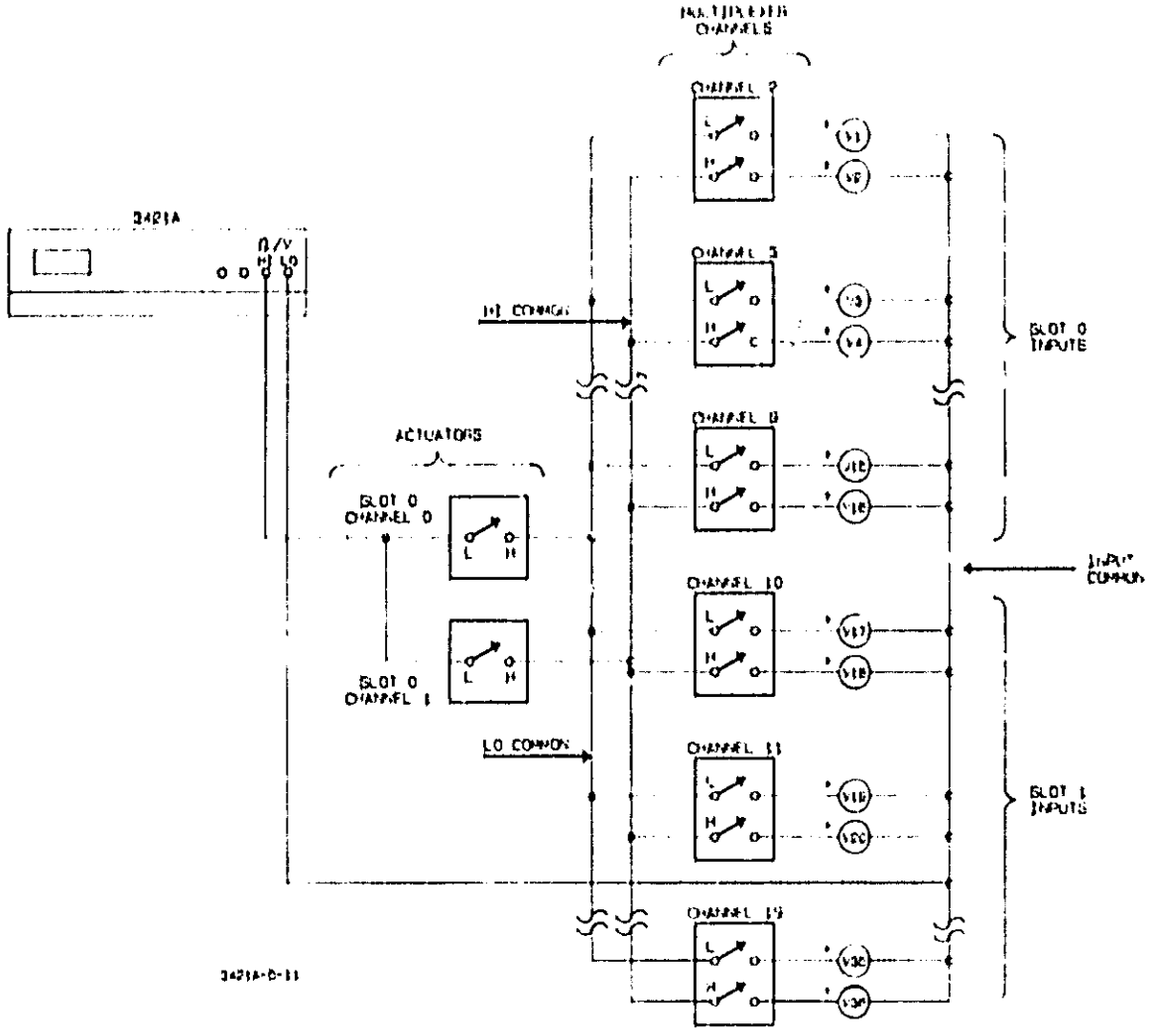



Figure 5-11. Single Ended Measurements

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.

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

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 measurement
   example
20 ! -HP- SF version
30 ! 3421A at address 901
40 DIM R(19)
50 OUTPUT 901 ;"OPN"
60 ! Measure 'HI' side of
   relay tower sources'
70 DISP "HI'S" @ DISP
80 OUTPUT 901 ;"CL"&I"   Close
   Actuator #I
90 OUTPUT 901 "DCV2-19"
100 FOR I=2 TO 19
110 ENTER 901 ; R(I)
120 DISP "CHANNEL NUMBER  ";I;"
    READING = ";R(I)
130 NEXT I
140 ! Measure 'LO' side of
   relay tower sources'
150 DISP "LO'S" @ DISP
160 OUTPUT 901 ;"OPN"&I" ! Open
   Actuator #I
170 OUTPUT 901 "CLSD" ! Close
   Actuator #0
180 OUTPUT 901 "DCV2-19"
190 FOR I=2 TO 19
200 ENTER 901 ; R(I)
210 DISP "CHANNEL NUMBER  ";I;"
   READING " R(I)
220 NEXT I
230 END
```

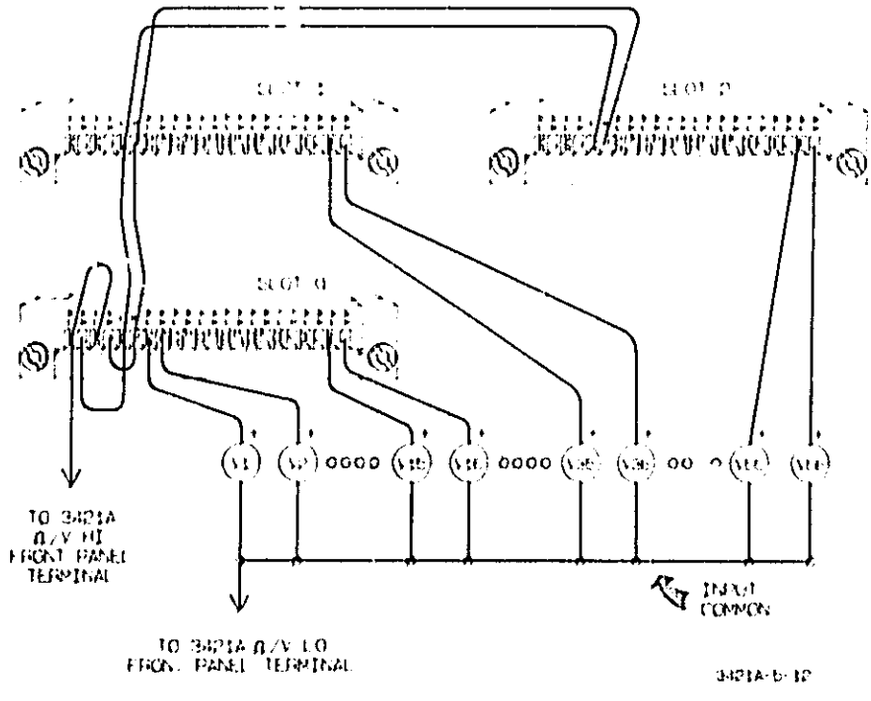



**Figure 5-12. Configuration for Single Ended Measurements**

## 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.

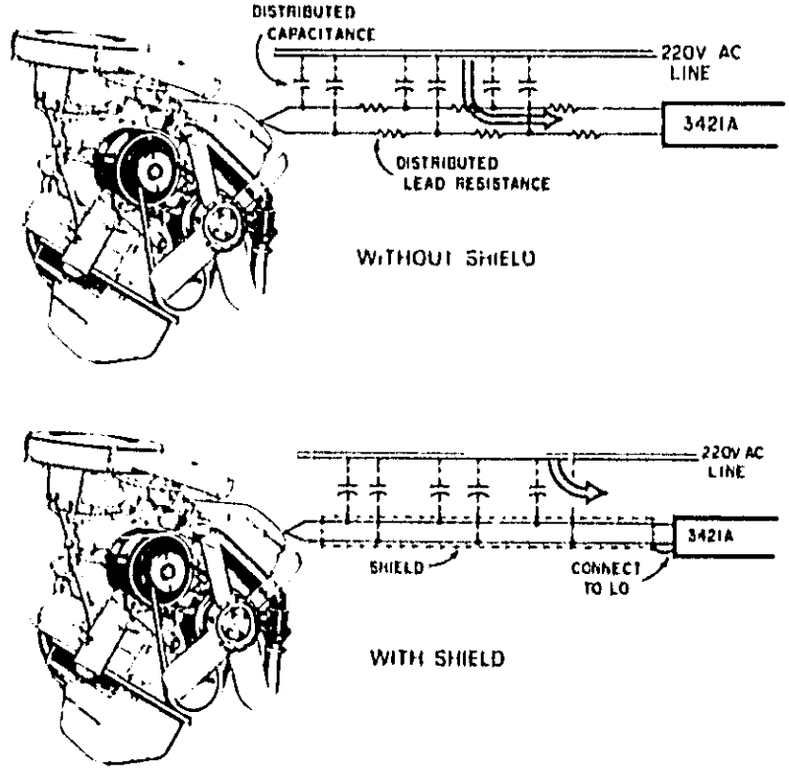



**Figure 5-13. Shielding**

# CHAPTER 5 CON'T

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 voltmete 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.

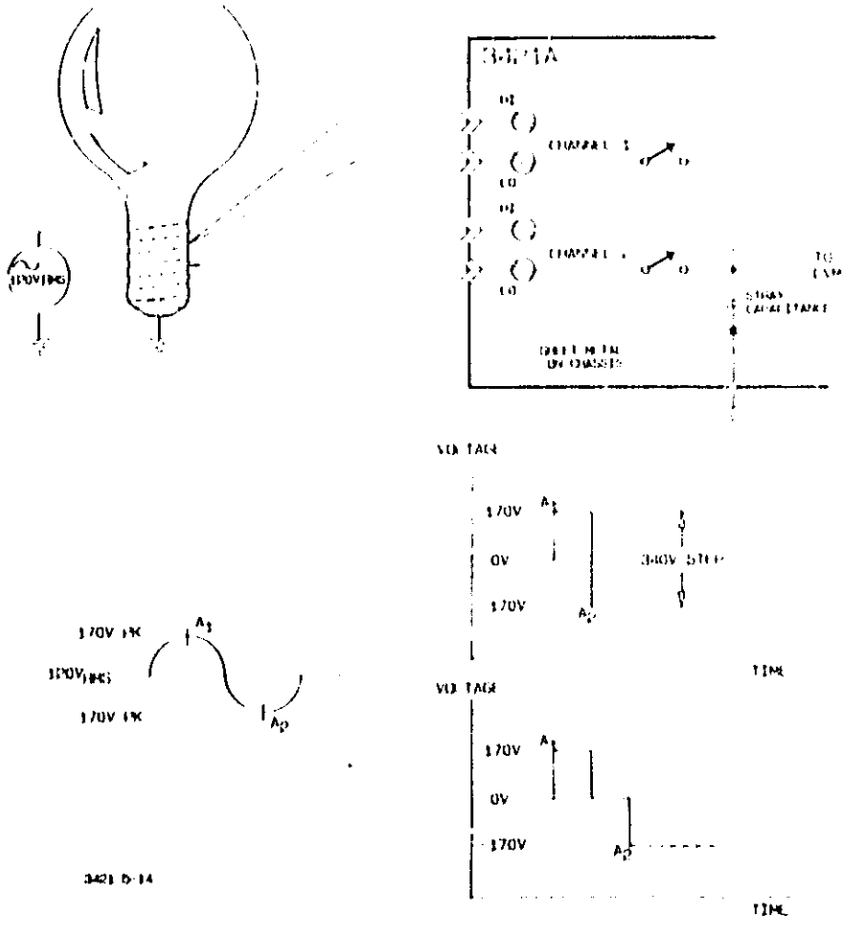



**Figure 5-14. Common Mode Noise**

## 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.

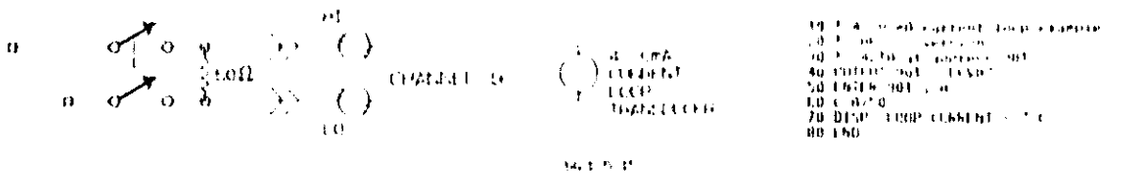


Figure 5-15. 4-20 mA Current Loop

# 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): $< 3\mu V$

All relays break-before-make

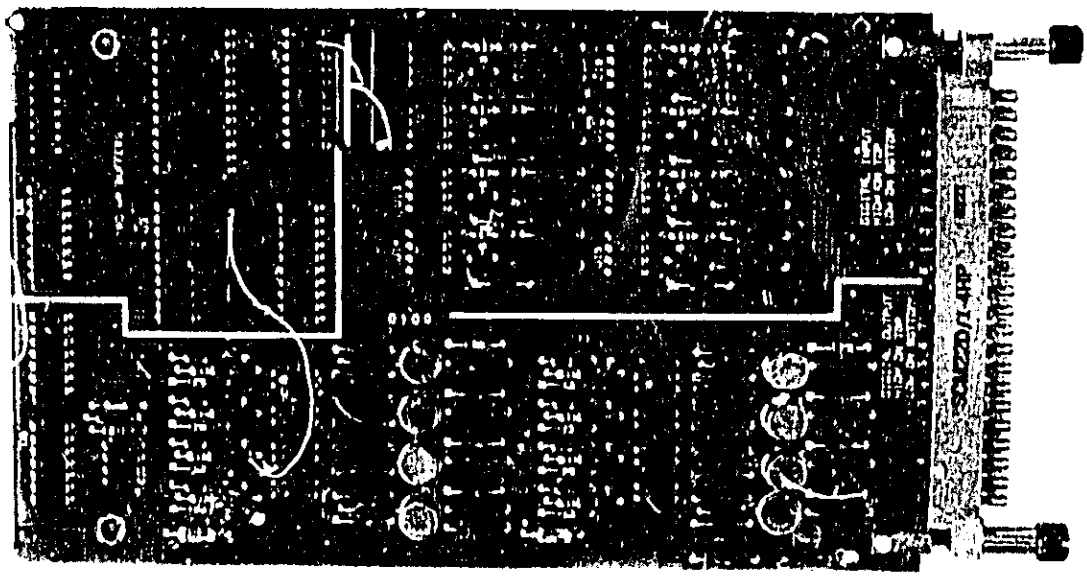
# CHAPTER 6

# 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.



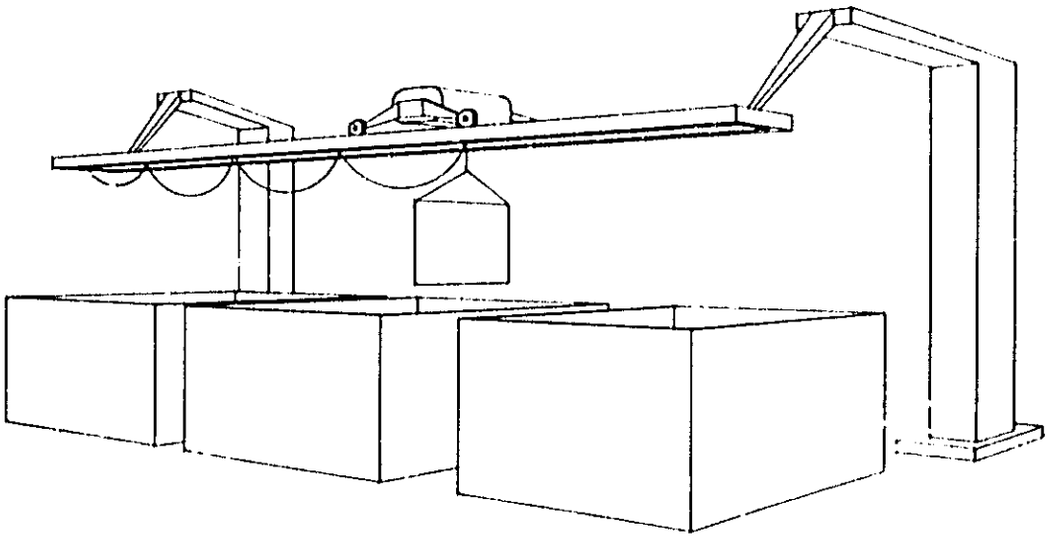
Each 44465A Digital I/O card provides one 8-bit input port and one 8-bit output port. Each bit is electrically isolated from the rest. Typical uses for the input port include limit and position switch monitoring and communicating with digital logic circuits. The output port can be used in low voltage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

**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

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
```

## 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

# 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.

```
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. |

## 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.

## 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)

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

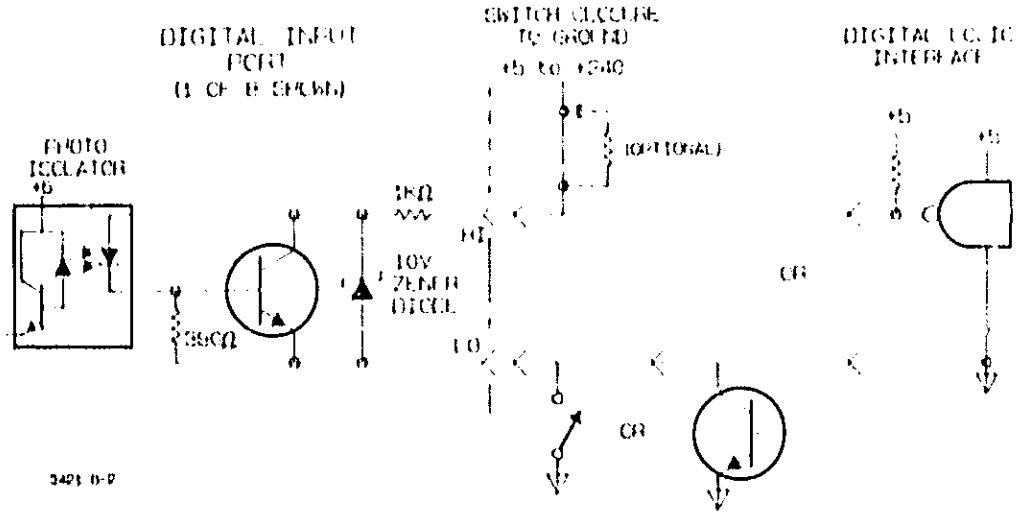
The Digital Trigger command (DTx) provides a way to externally trigger the 3421A voltmeter. The DT command monitors the bit at address "x", and when it goes low, a voltmeter T3 trigger command is executed. Trigger command T3 is used to trigger the voltmeter to make a measurement from each channel in 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.

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).

## 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.

```
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 Digital SET 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 Digital Clear command, DCi,[ab]c, clears (opens) the switches specified in the same manner as the Digital Set command closes switches.

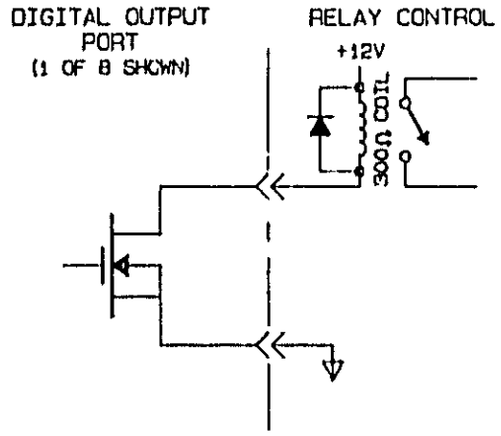
# Working With the Output Port

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

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.

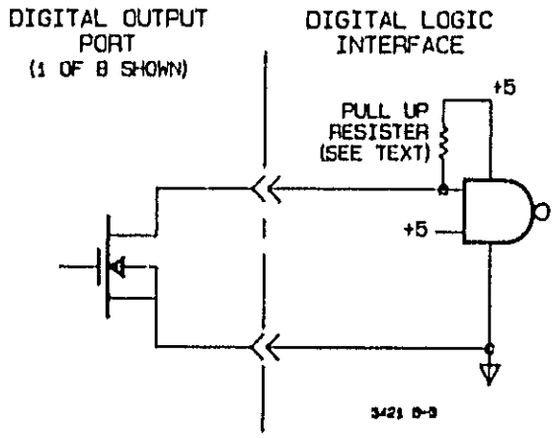
## Relay Control

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.



# 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, $\leq 300$mA current, $<.6$V Drop across switch

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

# CHAPTER 7

# 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.

# 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*<br>021*<br>022* | 44462A |
| Extra connector block for 10 channel Multiplexer | 44463A | 44463A |
| 8-Bit Digital I/O Assembly with connector block | Option 060 | 44466A |
| 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 | 10833A | 10833A |
| 2 Metre HP-IB Cable | 10833B | 10833B |
| 4 Metre HP-IB Cable | 10833C | 10833C |
| 0.5 Metre HP-IB Cable | 10833D | 10833D |
| 0.5 Metre HP-IL Cable | 82167A | 82167A |
| 1 Metre HP-IL Cable | 82167B | 82167B |
| 5 Metre HP-IL Cable | 82167D | 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.

# 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

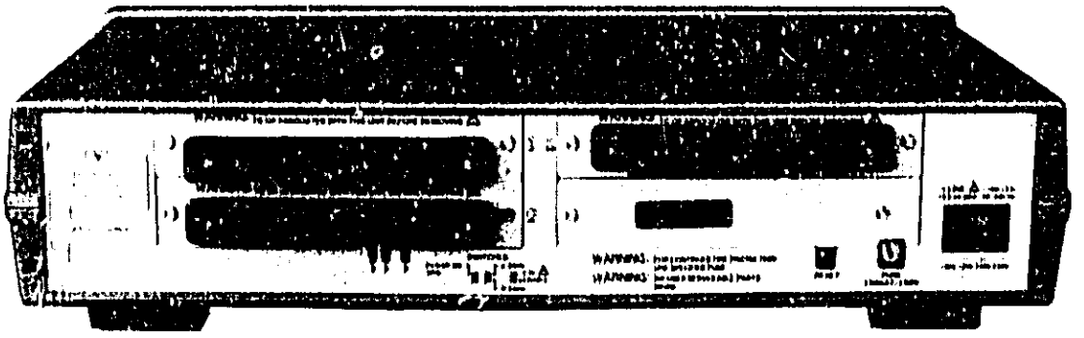
Your 3421A was carefully inspected before it left the factory. It should be free of mars or scratches and in proper working order upon receipt. You should, however, inspect the instrument for any damage that may have occurred in transit. If the shipping container or cushioning material is damaged, it 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.*

## Power Requirements

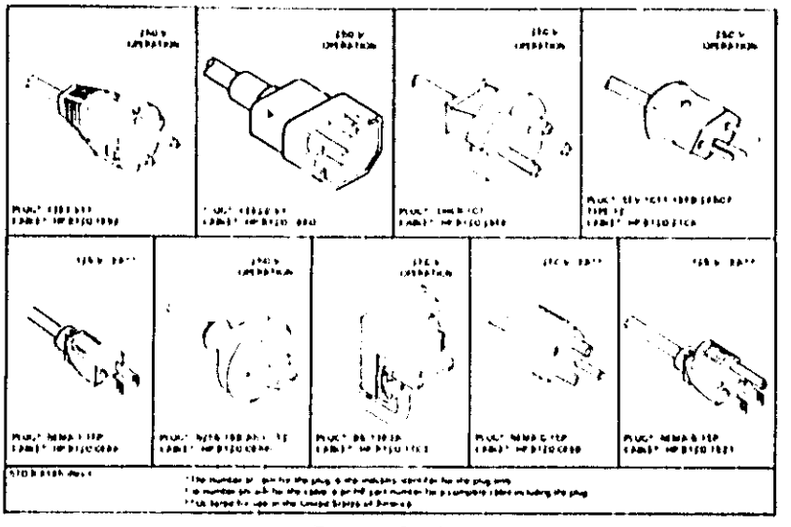
The 3421A requires a power source of 100, 120, 220, or 240 VAC (-10%, +5%), 48 to 440 Hz single phase. Maximum power consumption is 6 VA. Refer to the 3421A rear panel for the line voltage option label. Make certain the option marked on the label is the same as the nominal line voltage for your area. 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**

## 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 E'ectrotechnical 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 | 1.5A Time Delay |
| 316 | 100 | 60 | (hp Part Number 2110-0234) |
| 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.

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. |

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.

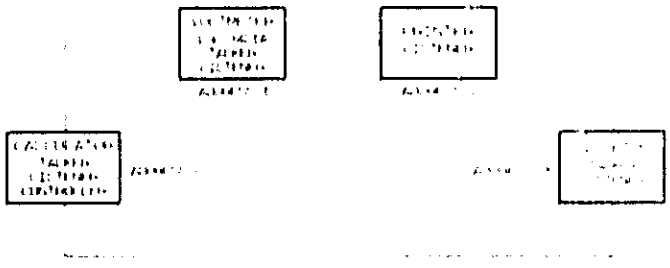
Indicates dangerous voltage (terminal fed from the interior by voltages exceeding 1000 volts must be so marked).

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

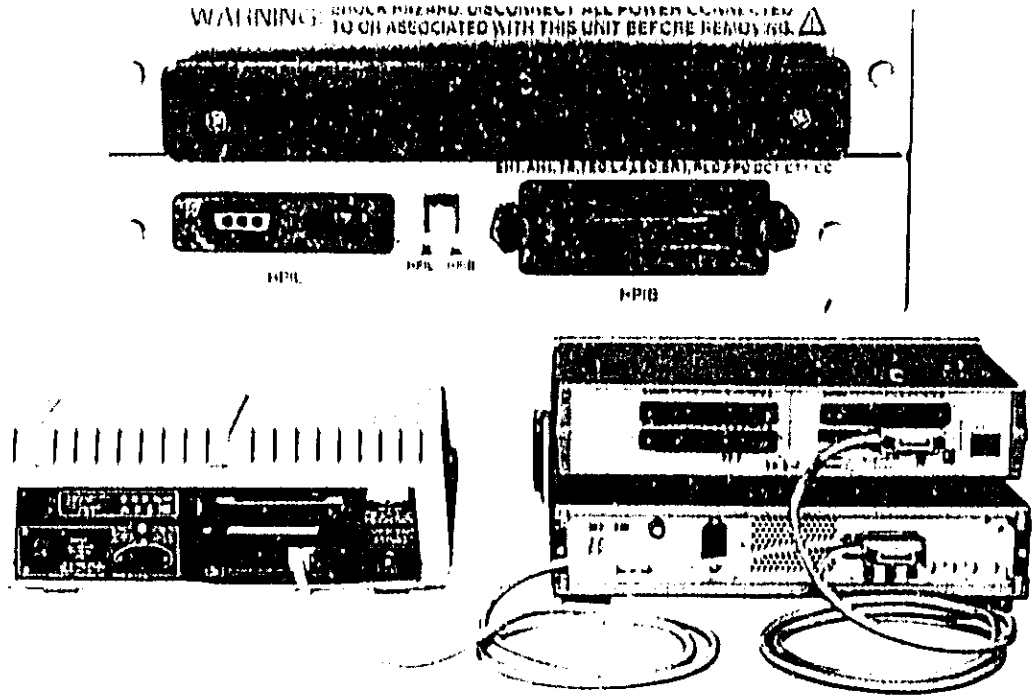
Although the 3421A may be connected anywhere in the loop, delays in triggering will be reduced if the 3421A is the first device in the loop. HP-IL connections to the 3421A are made by two cables, one going to the previous instrument in the loop (RECEIVE) and the other going to the next instrument in 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.

## 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 (6.6 feet) times the number of instruments to be connected, or 20 metres (65.6 feet), whichever is less.




HP-IB and Two Cable System

## 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.

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 addit on, -hp- does not warrant any damage that occurs as a result of the Buyers circu't, 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.

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.*

# 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 tran sit 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 clear ad periodically with a cotton swab dipped in isopropyl alcohol and then rinsed with deionized water. Let the panel thoroughly dry before using.

# 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 ≤ 85% 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% 9% | |
| 300 V | 301.000 | 1 mV | 10 mV | 100 mV | 10M ± 1% | 10M ± 1% 9% | |

**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 ≤ 85% 5½ Digit | 4½ Digit | 3½ Digit |
|---|---|---|---|---|---|---|
| AC NMR | 80 | 59 | 0 | 80 | 59 | 0 |
| AC ECMR | 140 | 120 | 60 | 140 | 120 | 60 |
| 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.

# 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 | .0364 + 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 | .0364 + 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

# 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<br>3kΩ for 300Ω | 3k through 30M |

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

## AC VOLTAGE

**Input Characteristics**

| Range | Maximum Display (4½ Digit) | 4½ Digit Resolution | Input Resistance | Maximum Input Voltage |
|---|---|---|---|---|
| 3 V | 3.0100 | 100μV | | Hi Lo<br>± 3V peak |
| 30 V | 30.100 | 1 mV | 10MΩ ± 1% | Lo terminal to earth:<br>± 150V peak |

**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 | 0.4 |
| N4 | 15.65 | 23.02 | .91 | 1.11 | 15.65 | 24.31 | 1.05 | G0 | .09 |
| N3 | 30.96 | 38.66 | 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 | 3.98 | | | 2.19 | 3.99 | 98 | G1 | 7.69 |
| N4 | 13.18 | 18.34 | 90 | 1.06 | 13.20 | 18.61 | 98 | G0 | 97 |
| N3 | 22.22 | 26.99 | 1.35 | 1.30 | 22.10 | 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
G1 .1 second gate time
G0 1 second gate time
G1 10 second gate time

## COUNTER

AC coupled zero crossing

**Frequency range:**

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%

# 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

21 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<br>± 150 V peak Lo-earth<br>250 Vac<br>150 VA Maximum |
| Voltage (Actuate) | 30 Vdc<br>250 Vac<br>2A Maximum |
| Contact Resistance (Actuate) | < 1 Ω |
| Thermal Offset (Scan) | < 3 μV |
| Average Switch Life | 5 × 10⁷ operations with proper contact protection |
| Maximum Switching Rate | 60 sec |
| Open Contact Capacitance | < 15 pF |
| Closed Channel Capacitance | < 90 pF with 1 Option 020<br>< 130 pF with 2 Option 020<br>< 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<br>2-9 | Actuate<br>1 of N Scan<br>150 VA Max |
| 021 | 0<br>1-9 | Actuate<br>1 of N Scan<br>150 VA Max. |
| 022 | 0-9 | 1 of N Scan<br>150 VA Max |

## REFERENCE JUNCTION COMPENSATION

| Operating Temperature 23 ± 5°C | Accuracy |
|---|---|
| Stable Environment (< 1°C deviations) | ± 1°C |
| Dynamic Environment (5°C step or 5°C hour maximum rate of change) | ± 3°C |

**Temperature coefficient for 0-16°C-28-50°C operating ranges**

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

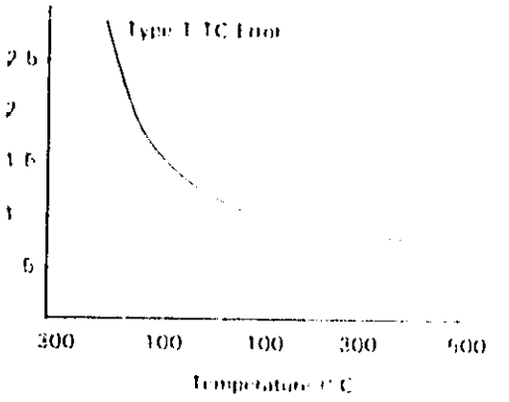
## TYPE T THERMOCOUPLE COMPENSATION

**Range:** 200°C to + 400°C

**Accuracy:** includes reference junction error, thermal offset, open 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, open 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 44460A):**

$Z_{in}$ 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

## 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 μ A
**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 16 DMOS FETS

| Input | Output Characteristics |
|---|---|
| Logic 1 | Low impedance 2Ω, sink 300 mA, 180 mV |
| 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:** 96 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, 36 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:** 0.6 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).

# 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 re-install the 3421A option assemblies.*

# CHAPTER 8

# 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 7 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.

**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

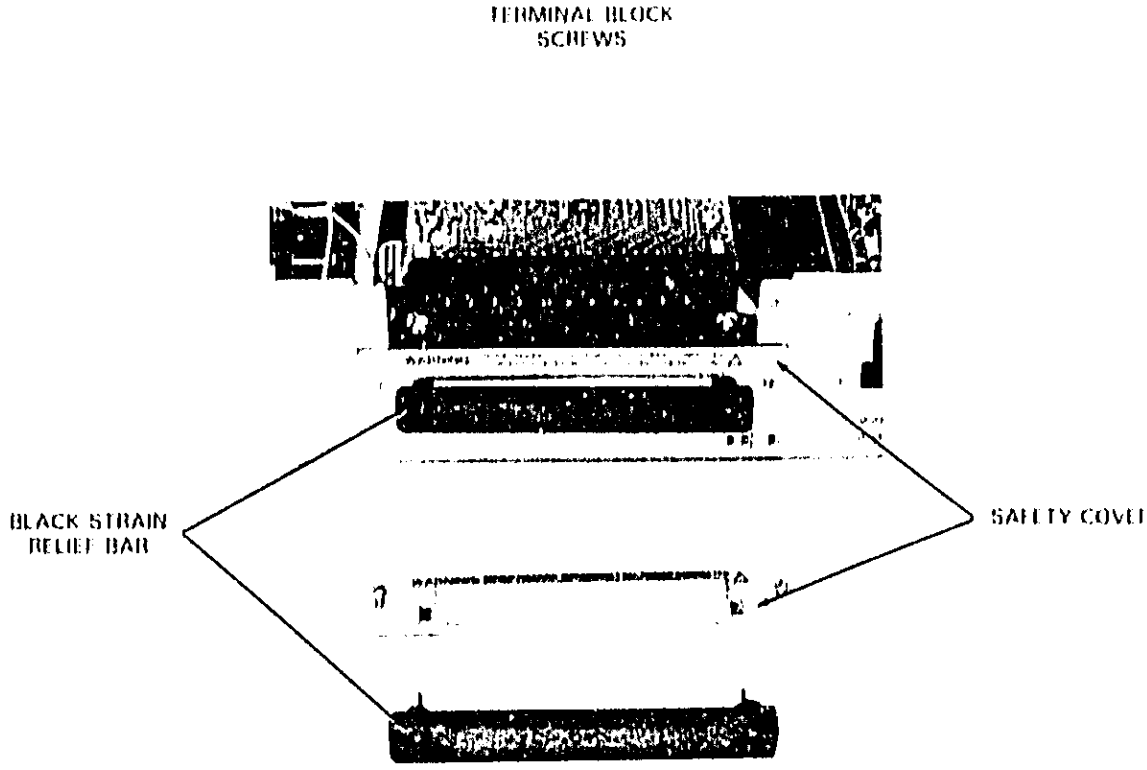
If wiring connections to external devices or transducers have already been made to the option assembly terminal blocks, you should first remove the terminal blocks. This is accomplished by:

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.




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.

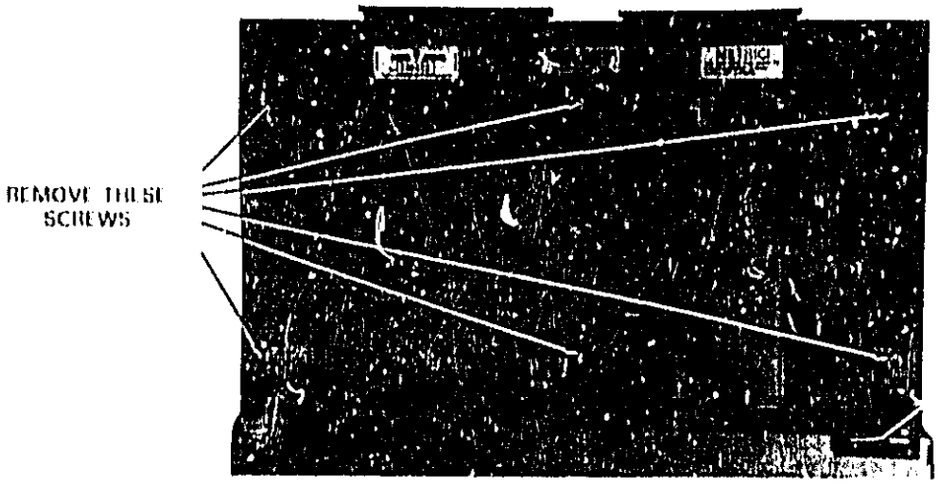
**NOTE**

*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.*

## 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.

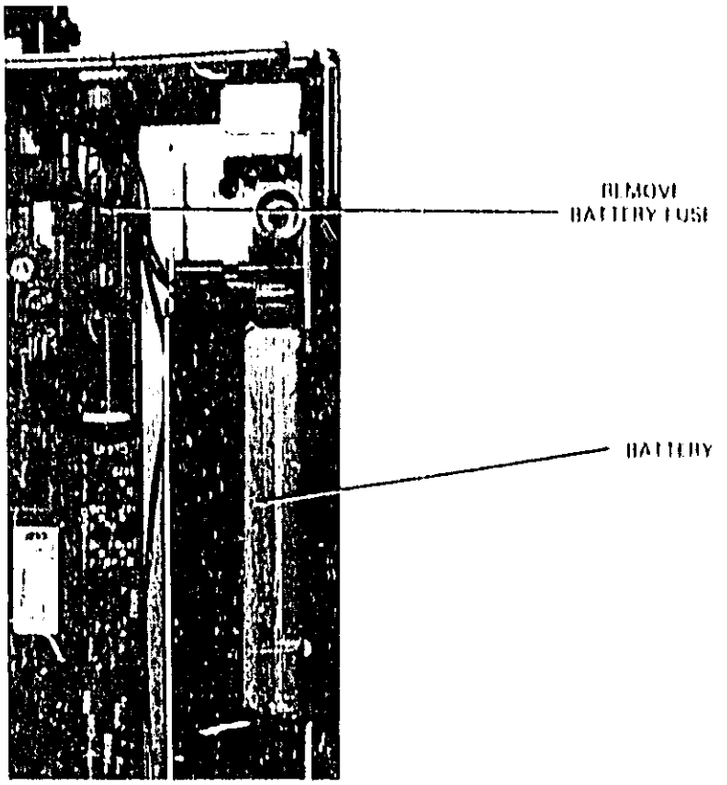
4. If the black strain relief bars and grey 'WARNING' safety covers have not been removed from the rear panel, they should be removed at this time.

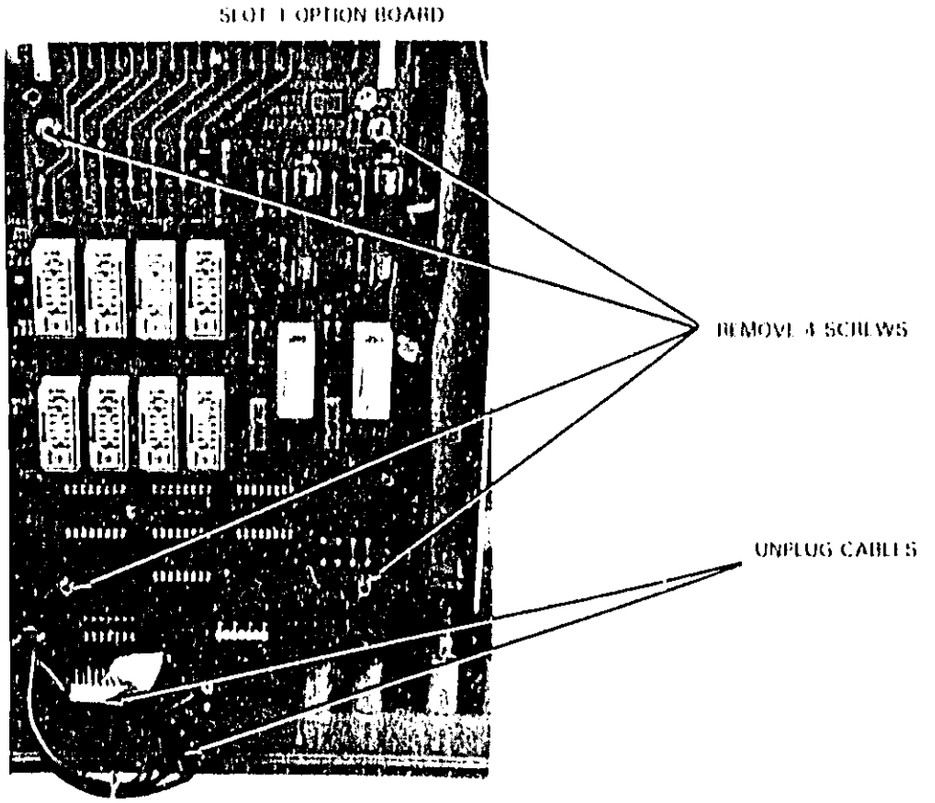
5. Remove the grey ribbon cable connector from the option in slot 1. Be very careful to lift the connector straight up from the option so as not to bend any of the pins on the connector. If the option in slot 1 is a 44462A Multiplexer option, remove the 4-wire voltmeter input cable from the motherboard.

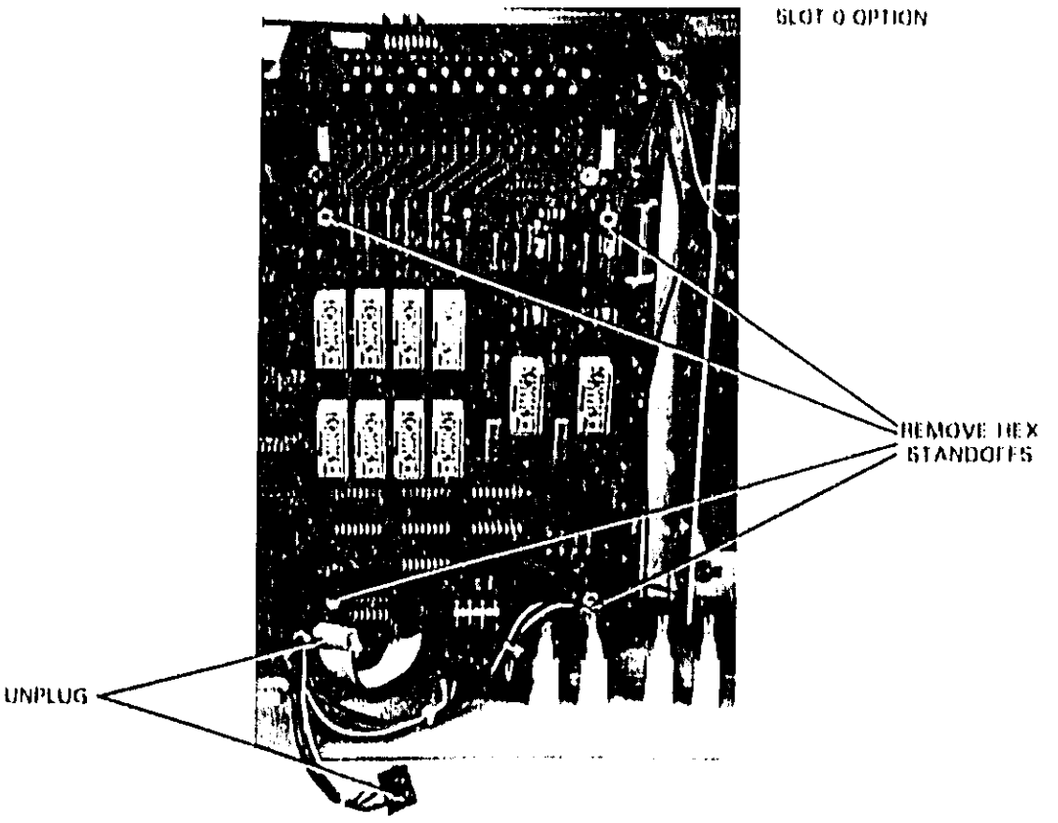
6. Remove the four screws that hold the slot 1 option in place.

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.


REMOVE
BATTERY FUSE
BATTERY


SLOT 1 OPTION BOARD
REMOVE 4 SCREWS
UNPLUG CABLES




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

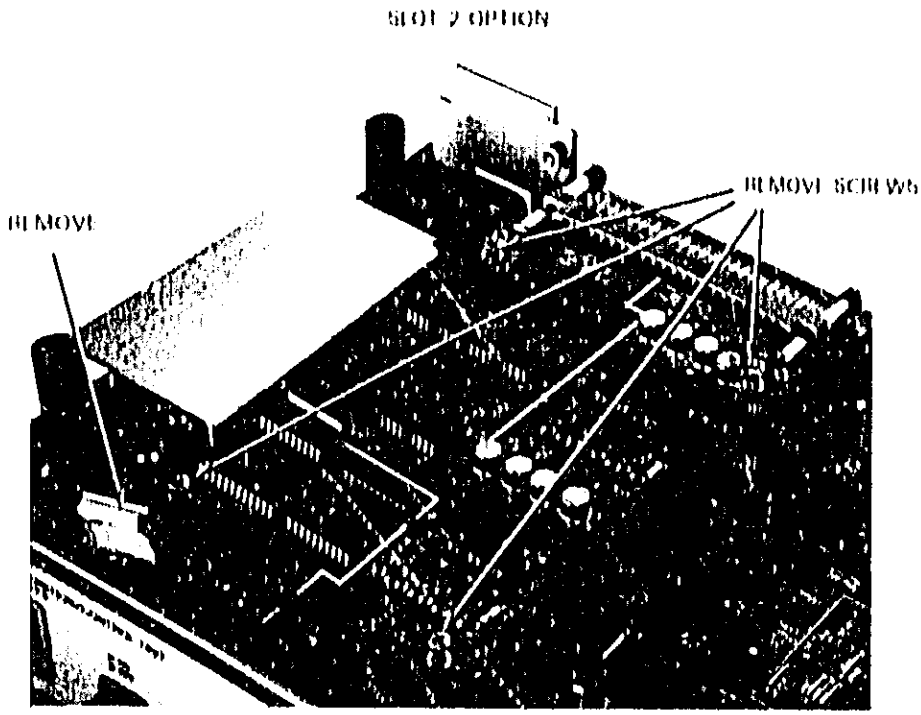
10. Leave the bottom hex standoffs in place securing the motherboard to the chassis.

**NOTE**

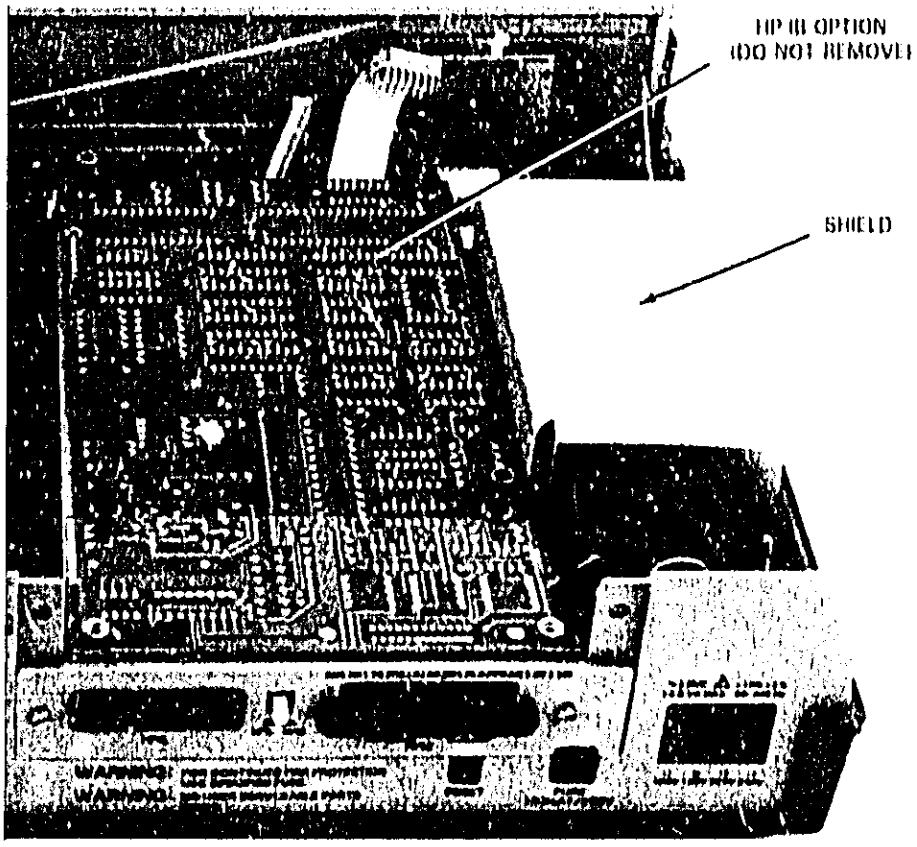
*The hex standoffs securing the motherboard to the chassis are shorter than the hex standoffs separating the two options in slots 0 and 1.*

*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.*

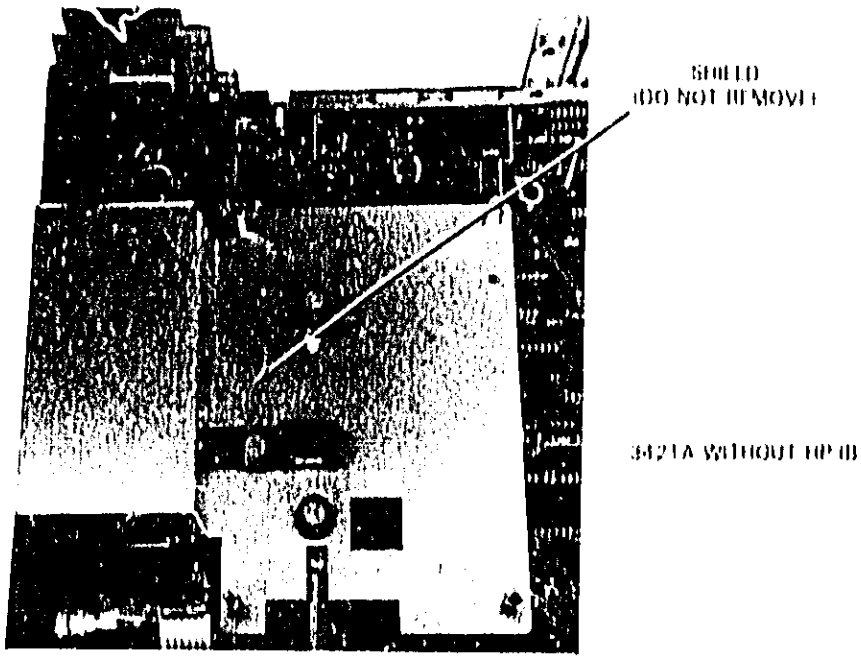
11. To remove the option occupying slot 2, remove the ribbon cable connector and the 4 wire voltmeter cable if present. Remove the four screws that hold the option assembly in place and remove the option.




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




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.*

Before installing an 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 interfering 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.

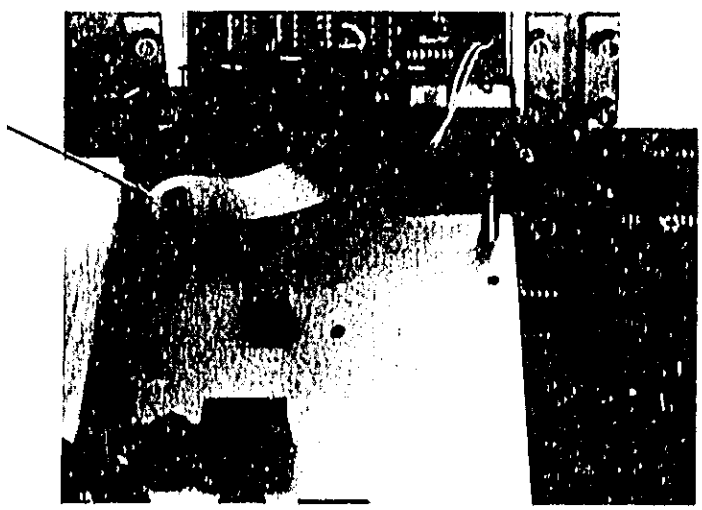
3. Plug the appropriate terminal block edge connector onto the option assembly in slot 2.

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 44732A 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

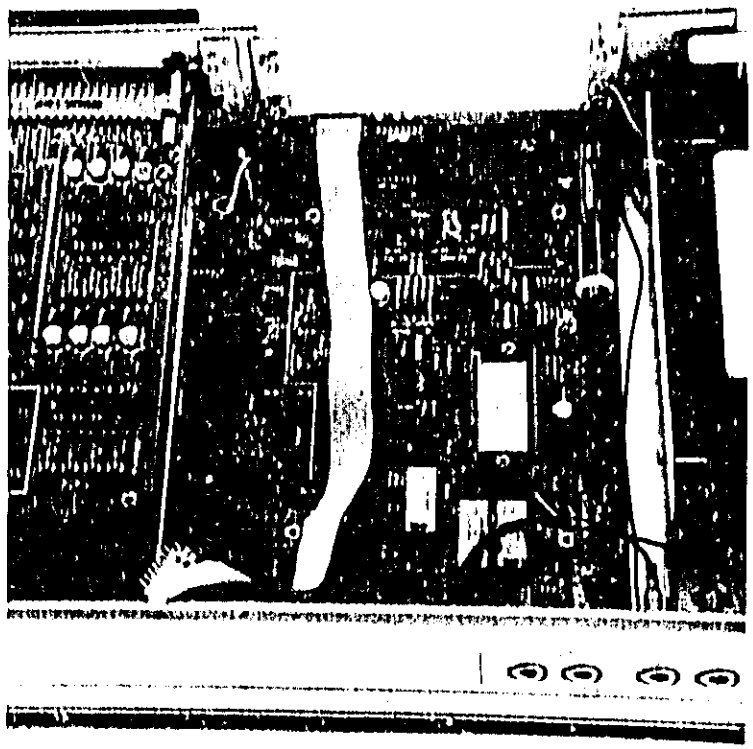
ROUTE CABLE AROUND STANDOFFS
(THIS CABLE ROUTING IS THE SAME
WHETHER HP-IB OPTION IS INSTALLED
OR NOT)



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.

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.

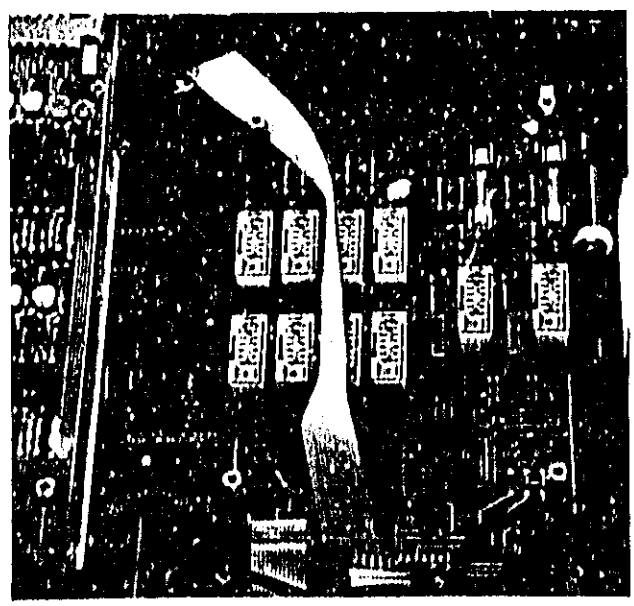
**NOTE**

*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 J601 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.

14. Plug the ribbon cable into the slot 1 option assembly 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 ball 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.

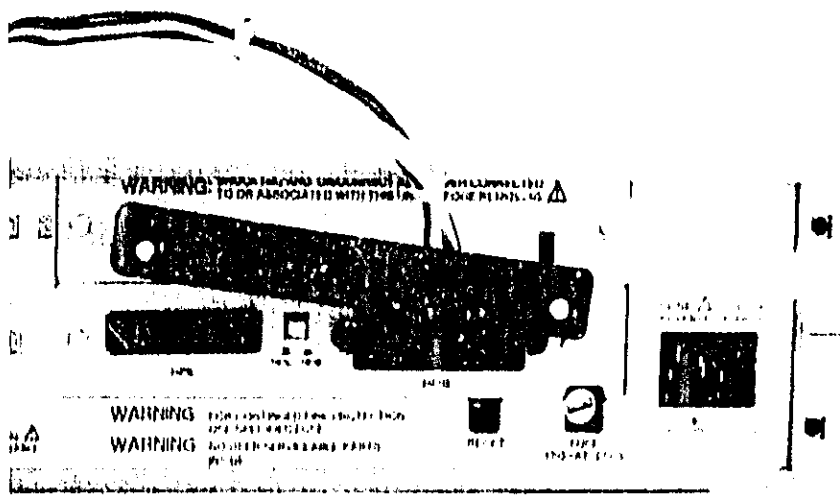
Finally, once the top cover is in place, hold the two halves of the case together and turn the instrument upside down. Tighten the six bottom screws.

# 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.



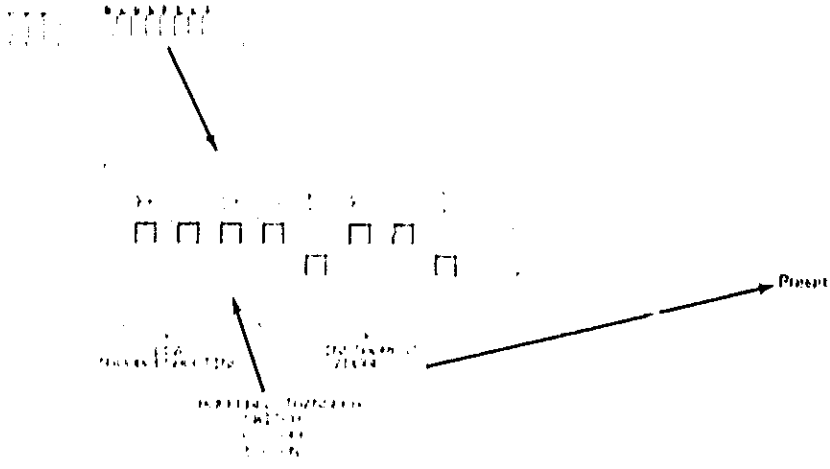
# HP-IB

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 |

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**

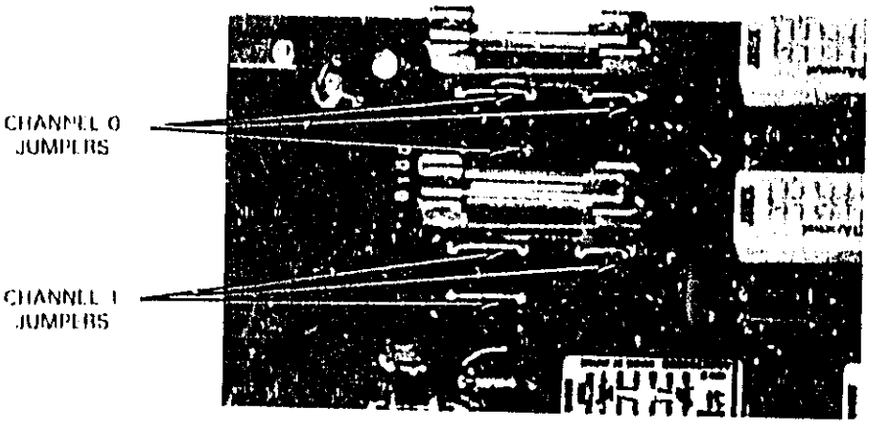
*In case of a component failure or programming error, any voltage that is input to a multiplexer assembly may be present on any other terminal of any installed multiplexer assembly as well as the 3421A front panel terminals. Likewise, any voltage that is input to the 3421A front panel terminals may be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

## Actuator/Multiplexer Jumpers

Channels 0 and 1 on each multiplexer 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.

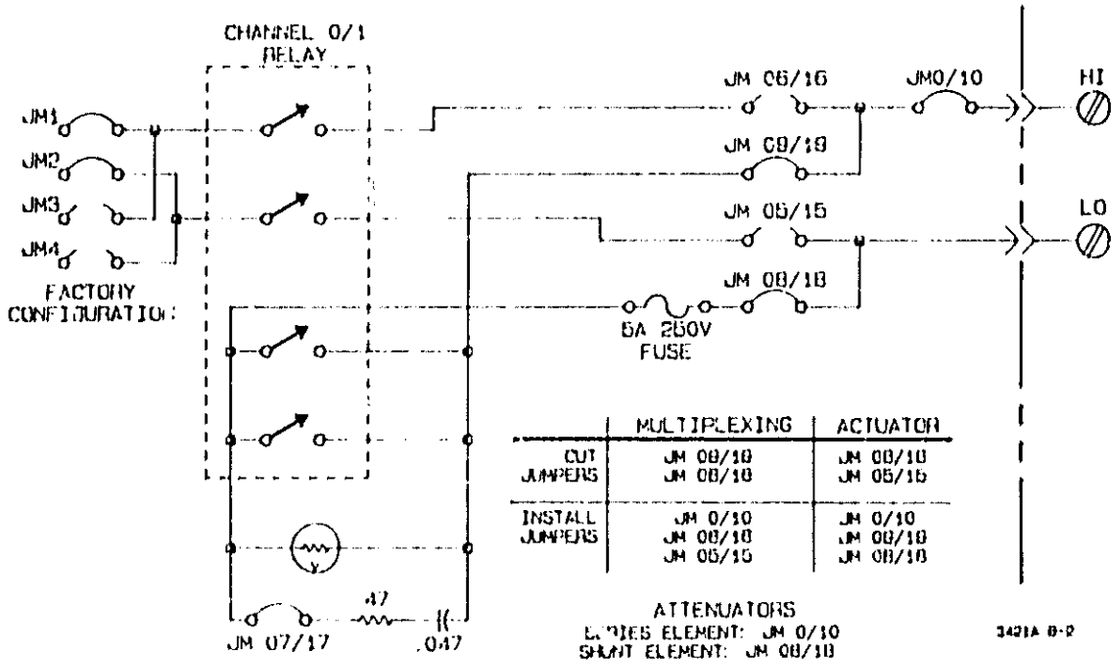
The following diagram and chart shows which jumpers need to be in place for channels 0 and 1 to be configured as actuators and which jumpers need to be in place for channels 0 and 1 to be configured as multiplexers. When a 10 Channel Multiplexer Assembly is ordered factory installed, it can have one 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).

## NOTE

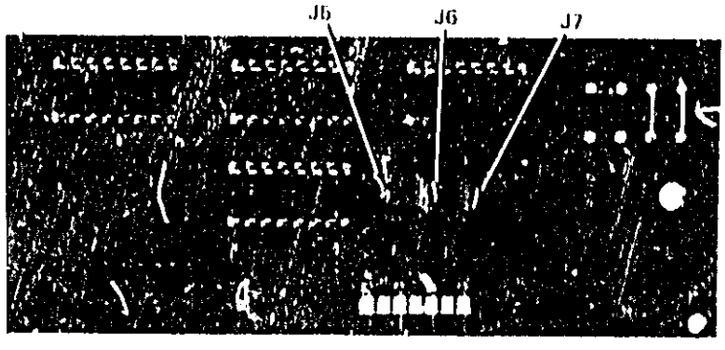
*Factory installed Option 020 and field installed Kit 44462A have been available since the introduction of the 3421A. Early versions of Option 020 and Kit 44462A had the same channel configuration as current options, except that they also had the built-in 10:1 divider jumper of channel 2 in place (i.e., 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.*




| | MULTIPLEXING | ACTUATOR |
|---|---|---|
| CUT JUMPERS | JM 08/18<br>JM 08/18 | JM 08/18<br>JM 05/15 |
| INSTALL JUMPERS | JM 0/10<br>JM 08/18<br>JM 05/15 | JM 0/10<br>JM 08/18<br>JM 08/18 |

## 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:

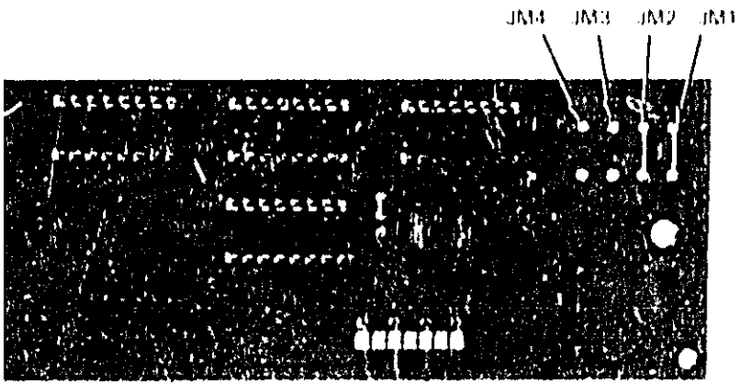
| J5 | J6 | J7 | Configuration/Type |
|---|---|---|---|
| 0 | 0 | 0 | No actuators, all 10 channels are configured as multiplexers. |
| 0 | 0 | 1 | Channel 0 is an actuator, all others are multiplexers. |
| 0 | 1 | 0 | Channel 1 is an actuator, channels 0 and 2-9 are multiplexers. |
| 0 | 1 | 1 | Channels 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 nonexistent or that it is a 44465A Digital I/O Assembly. This can cause substantial confusion when attempting to close channels or make measurements.*

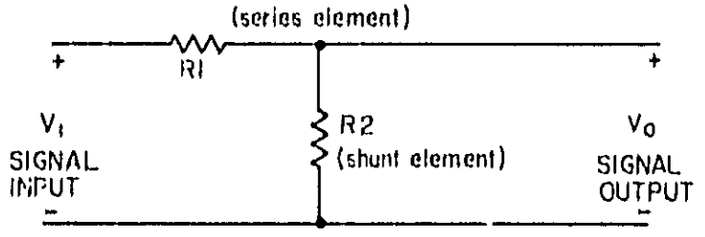
## 2- and 4-wire Ohms Measurements

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

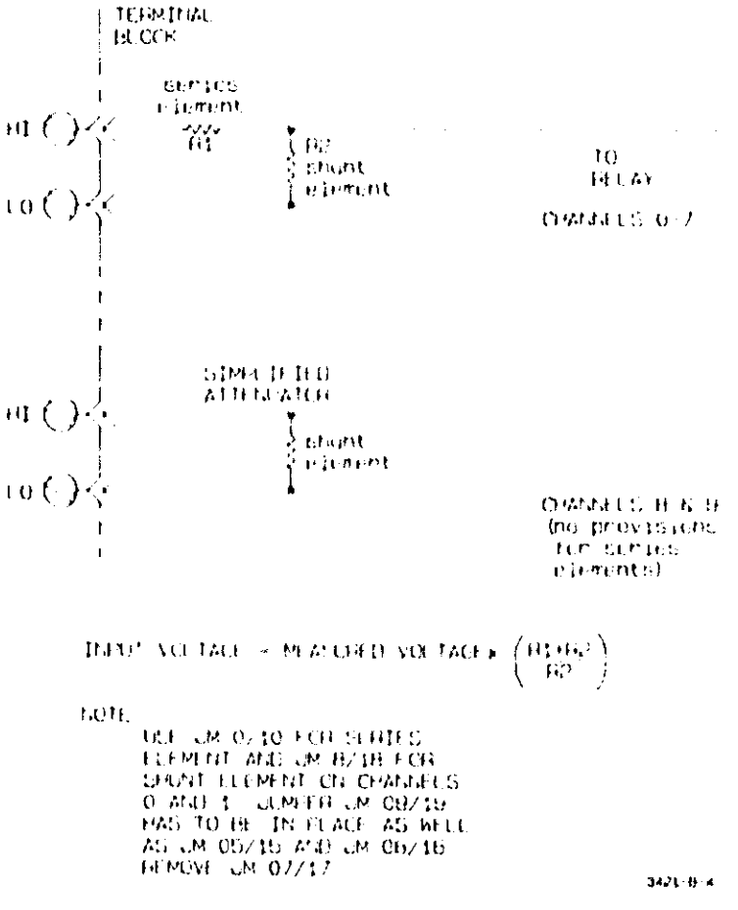
Provisions are made on the 44462A circuit board for attenuators to be installed on all but two channels (channels 8 and 9). An attenuator is composed of two resistors that act as a voltage divider. Consider the following diagram.



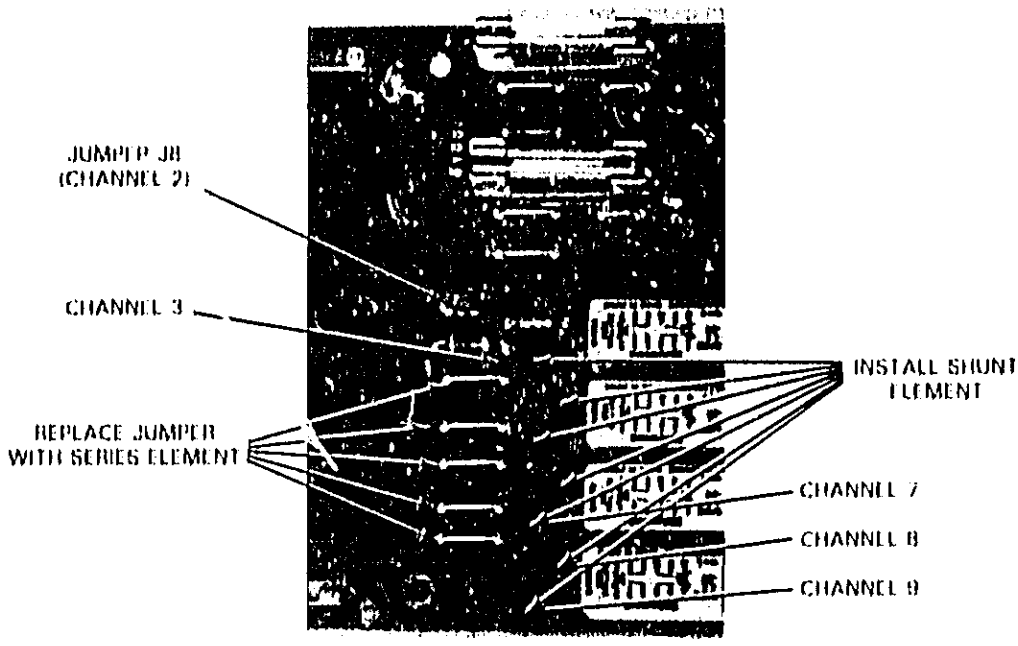

$$V_O = V_I * (R2/(R1+R2))$$

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.



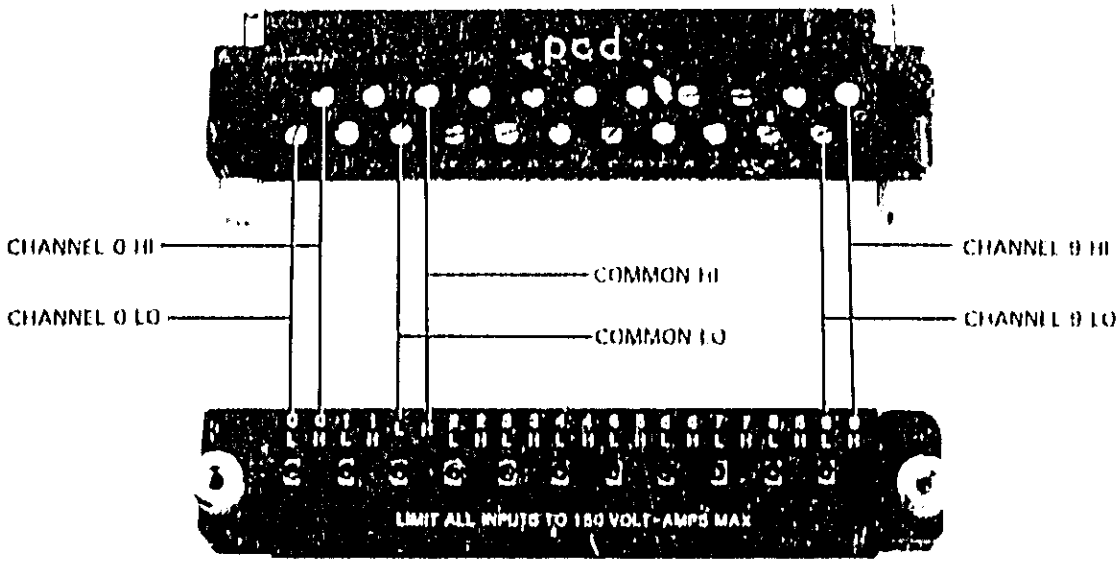

Channels 8 and 9 can only have shunt elements built across their signal paths. An example of where this would be useful is with 4 - 20 mA transducers. A 50 Ohm resistor, ± .1%, .5 watts (-hp- part number 0699-0064) can be placed across the signal path. The resultant voltage drop (transducer current through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




The Terminal Block Edge Connector

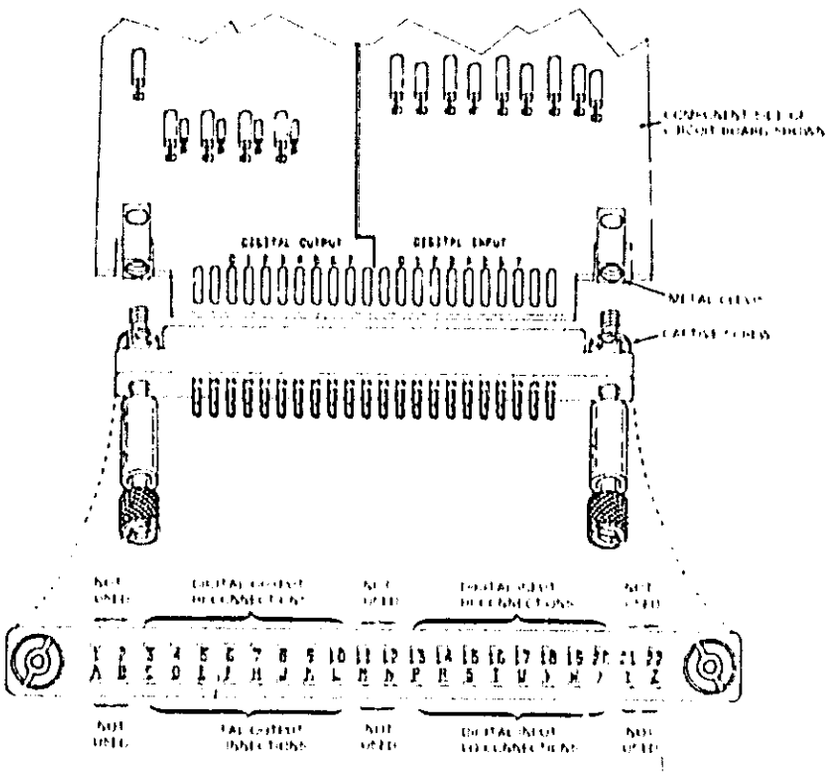
The following photograph shows the channel connection sequence for the terminal block. Extra terminal blocks are available under the -hp- part number: 44463A.

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.



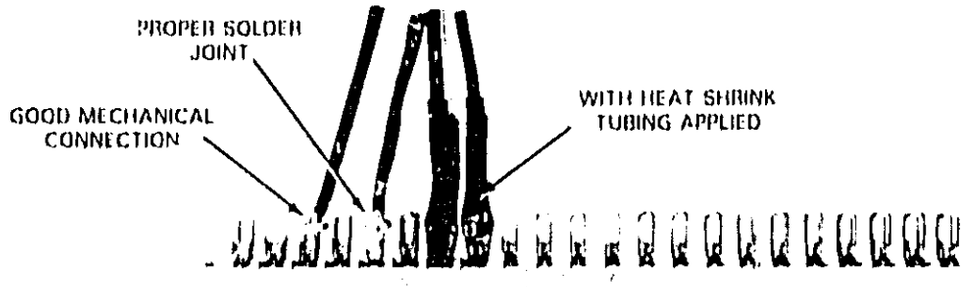
# Installing the 44465A Digital I/O Assembly

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.




## 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.

# CHAPTER 9

# CHAPTER 9
# 44464A
# Breadboard Option
# Option 040

## Introduction

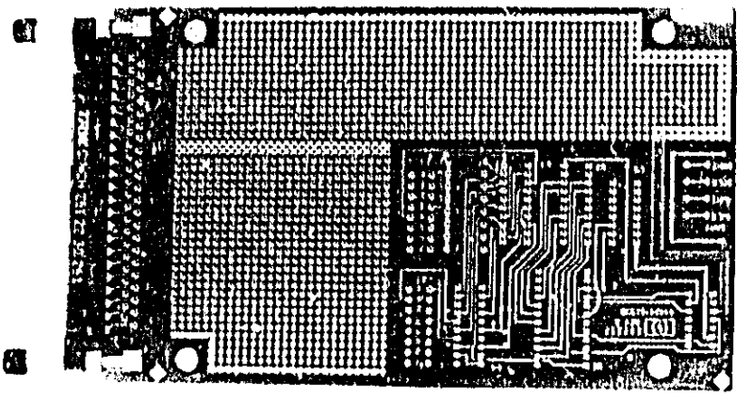
This chapter provides the technical information necessary for the design engineer or electronic technician to use the 44464A breadboard assembly with the 3421A Data Acquisition Control Unit. This chapter is NOT intended for use by non-technical personnel.

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.



## 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.*

# 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 |

# 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 1$\mu$F tantalum filter capacitor and two .01 $\mu$F 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.

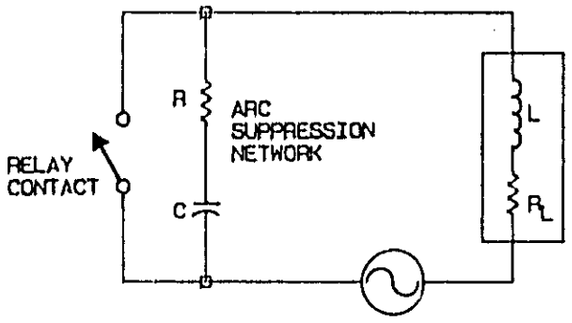
The following simplified design equations for an RC arc suppression network, will usually provide adequate protection. However, since the R and C values involve parameters difficult to determine precisely, such as the type of relay used, wiring

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: $C \geq ((Io/300)^2) \cdot L$ 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 minimze 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.

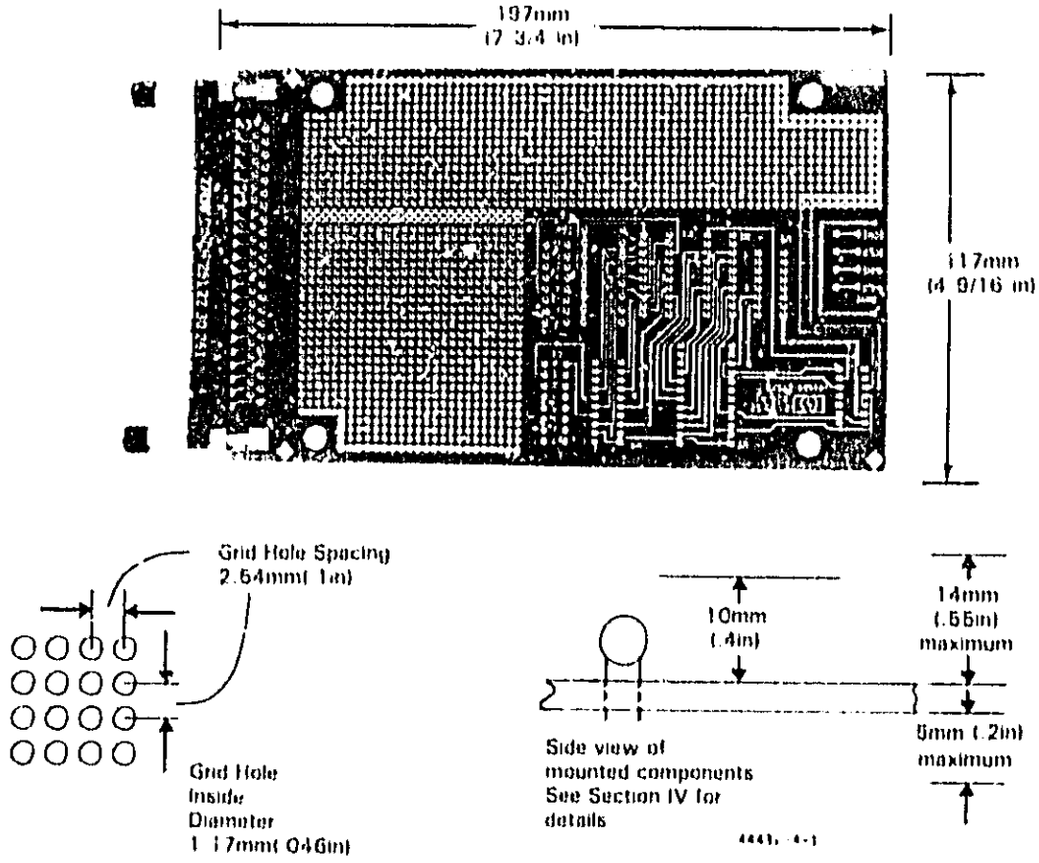



## Radiated Noise

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.

# The Circuit Board

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



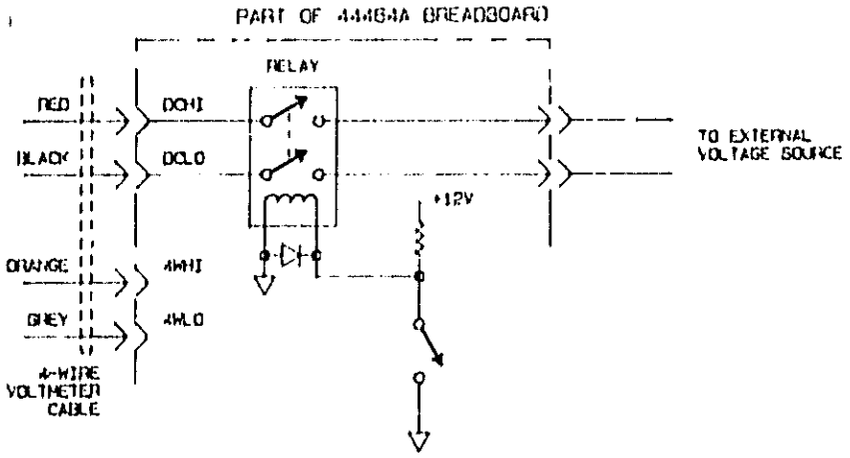

# Voltage and Resistance Measurements

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.

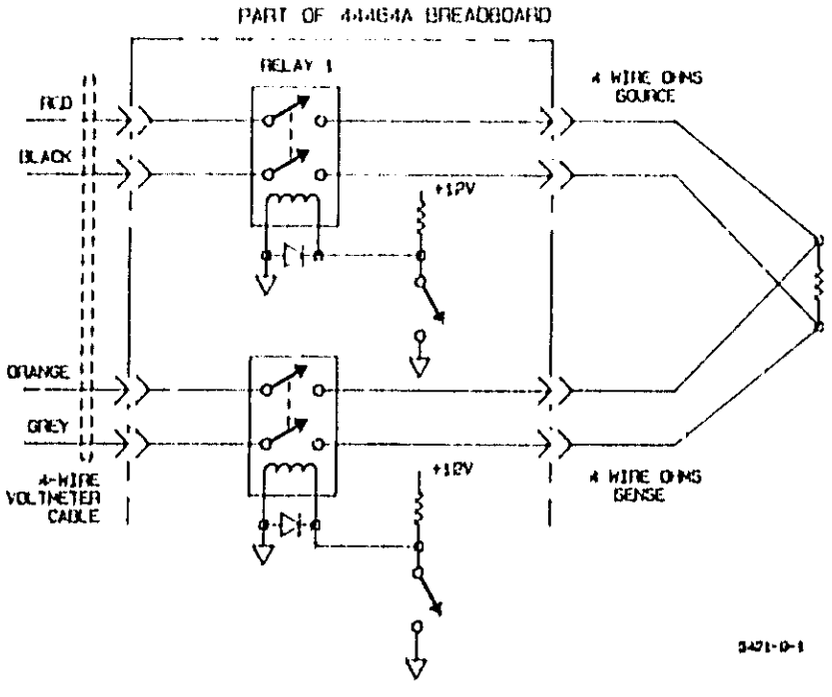
Second, close the relay on the breadboard assembly. This can be done with the BIT command, described later in this chapter.

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.



# Counter and Totalize

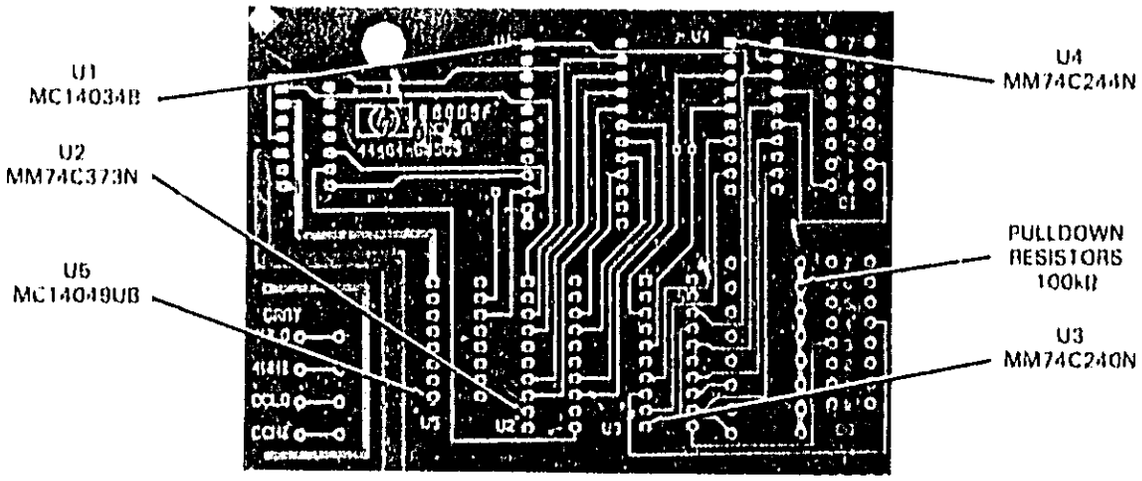
Counter and totalize measurements, like voltage and resistance measurements, are made through the DCL and DCH pins. The same constraints apply as for voltage measurements except that the FRQ command will be used for frequency measurements and TOT for totalizing.

# 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.*

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 device , 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.

| 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 ;"BIT1."
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.

## 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

(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.

## 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

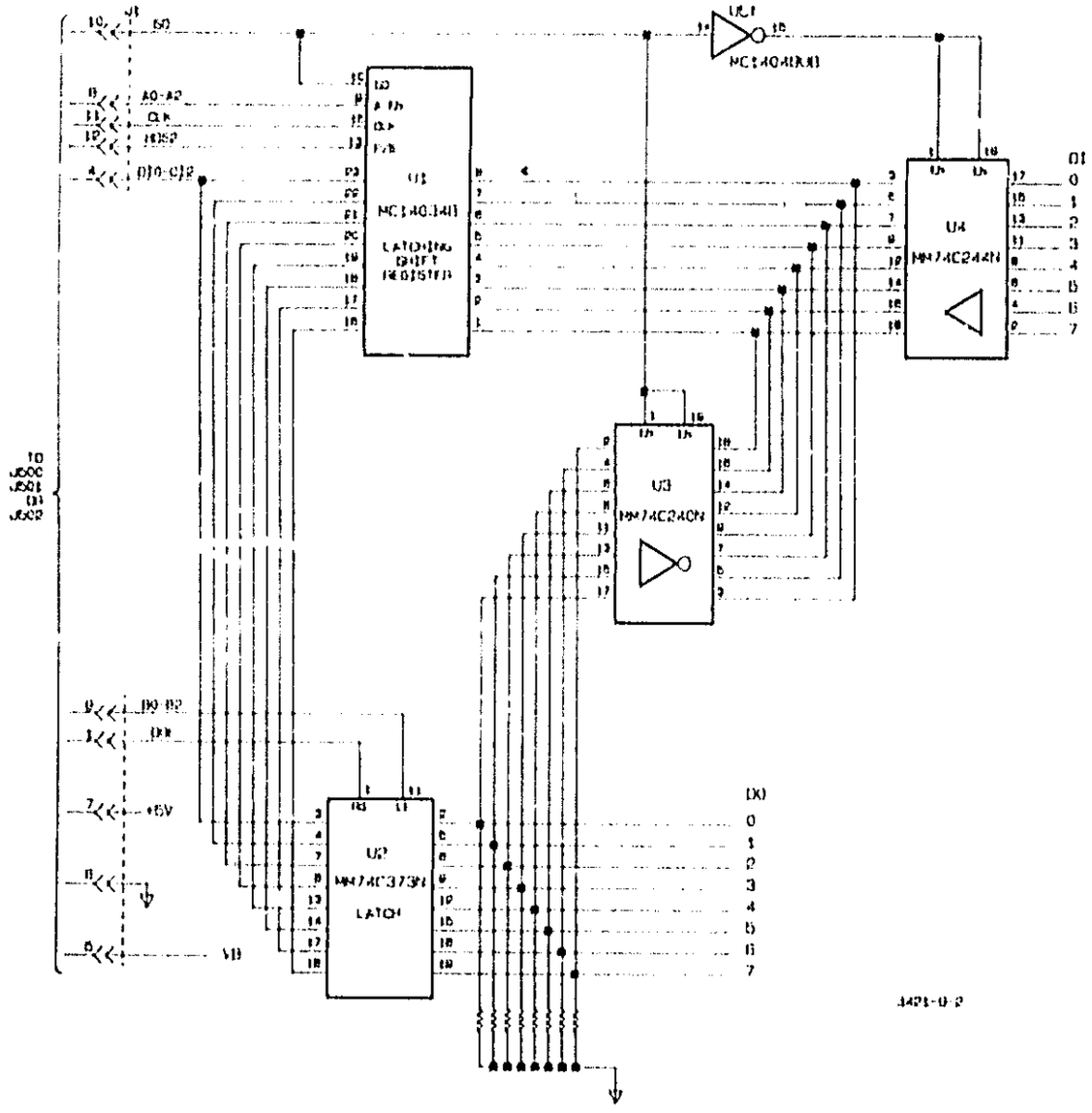
The Digital SET command, DSi,[abc], sets the output port bits on the card specified by "i" to the configuration specified by the decimal number [abc]. All bits not specified by [abc] remain unchanged. The value [abc] represents the sum of the values of the bits you wish to set. Use the bit value chart 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

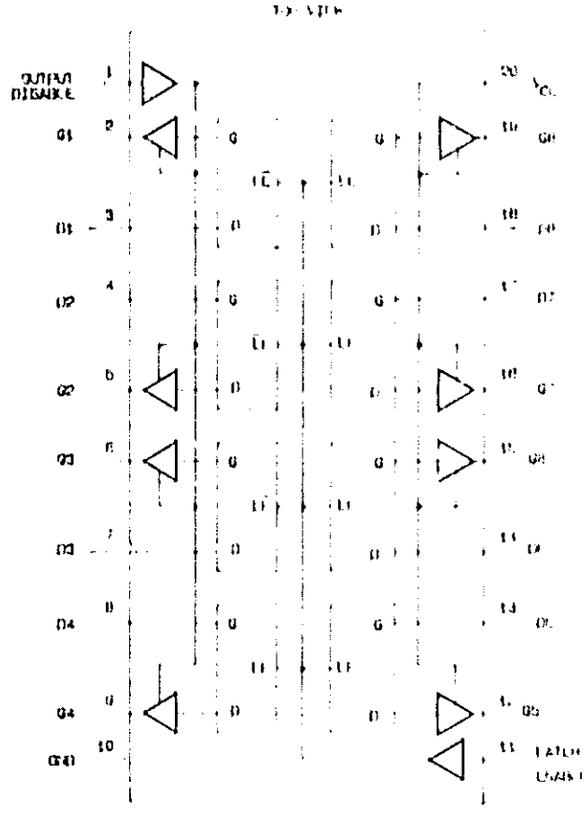
The Digital Clear command DCi,[abc], clears the bits specified in the same manner as the Digital Set command set bits.

# Theory of Operation

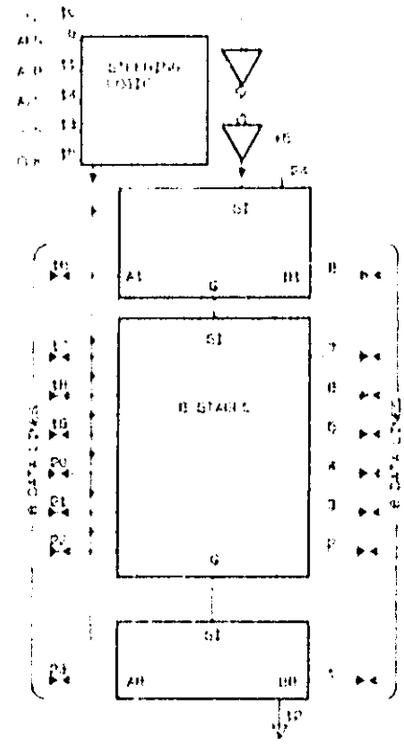
This simplified theory of operation is designed to help you understand the operation of the 8-bit input/output ports. Also, should problems occur in the input/output port, this information can assist you in troubleshooting. The following diagram illustrates the major blocks of the ports.



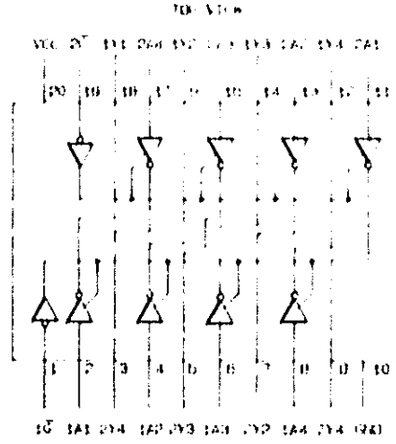
Commmunication between the 3421A internal microprocessor and the 44464A breadboard is carried on serially. U1 is an 8-bit bidirectional parallel/serial input/output bus register. This means that information from the input port, through U4, is converted to serial information by U1 and sent to the 3421A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



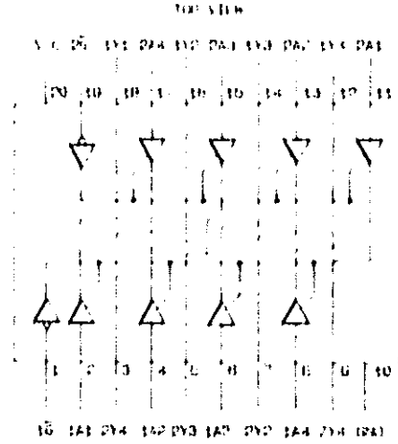
U2



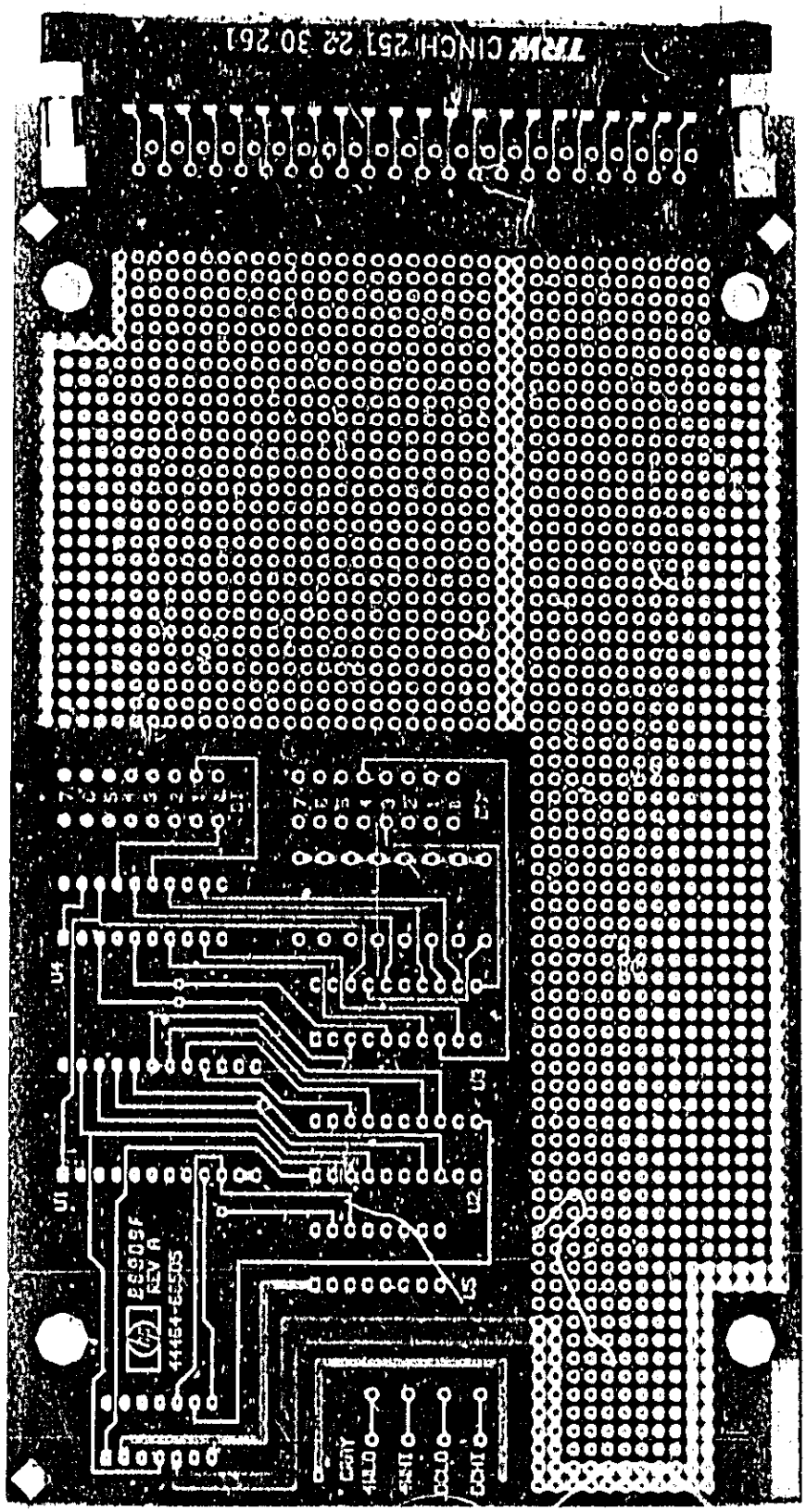
U1

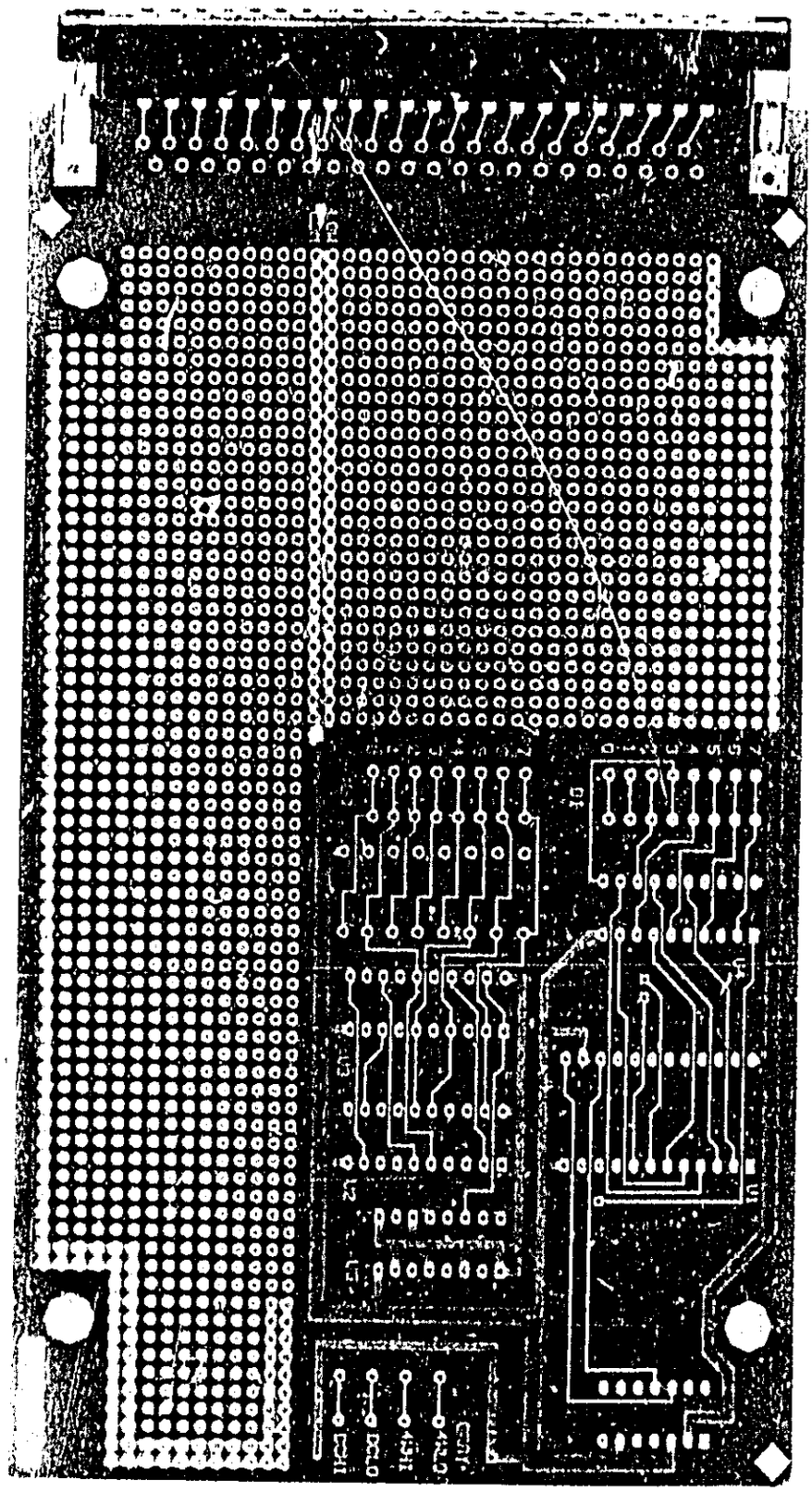


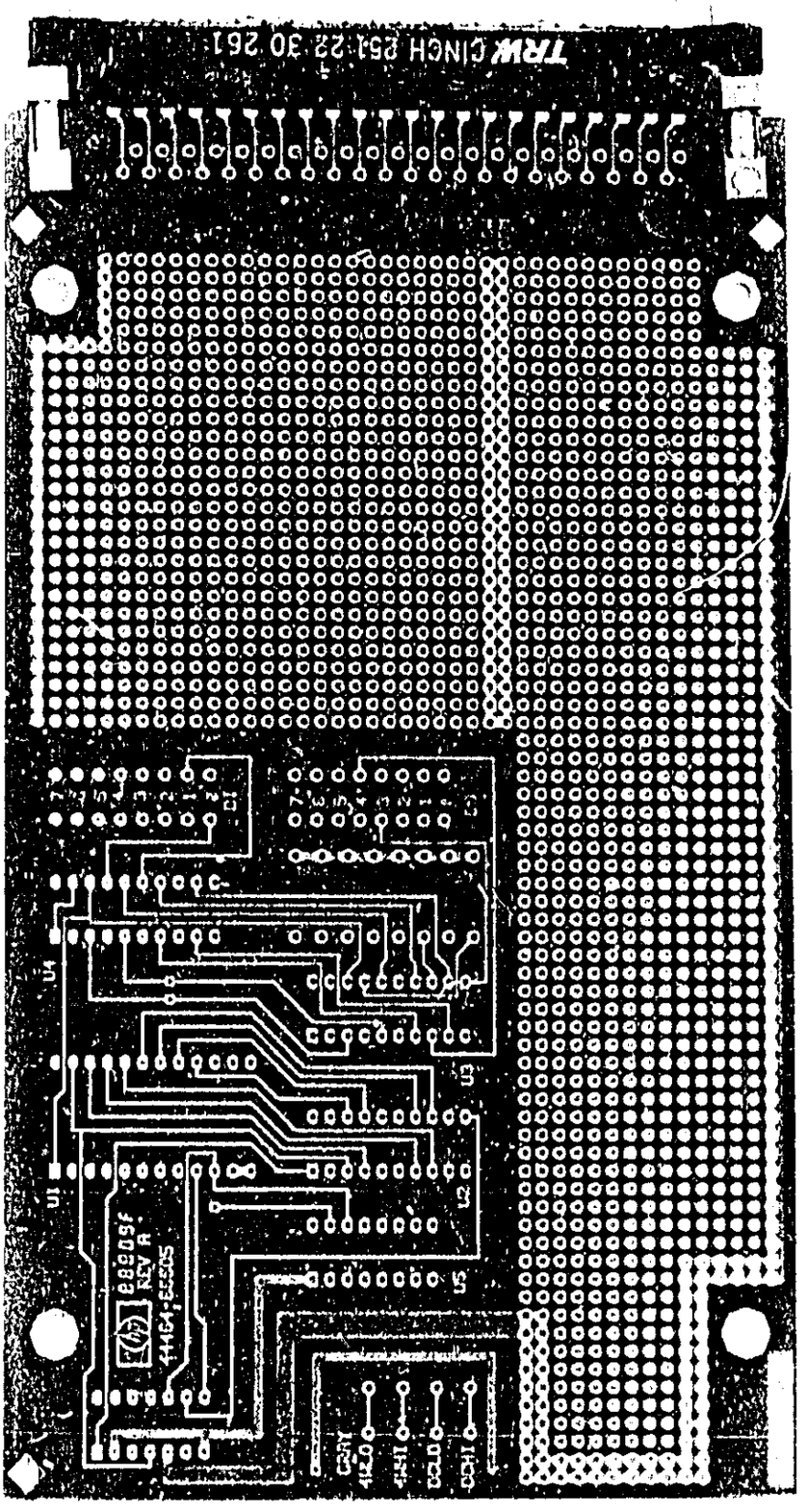
U3

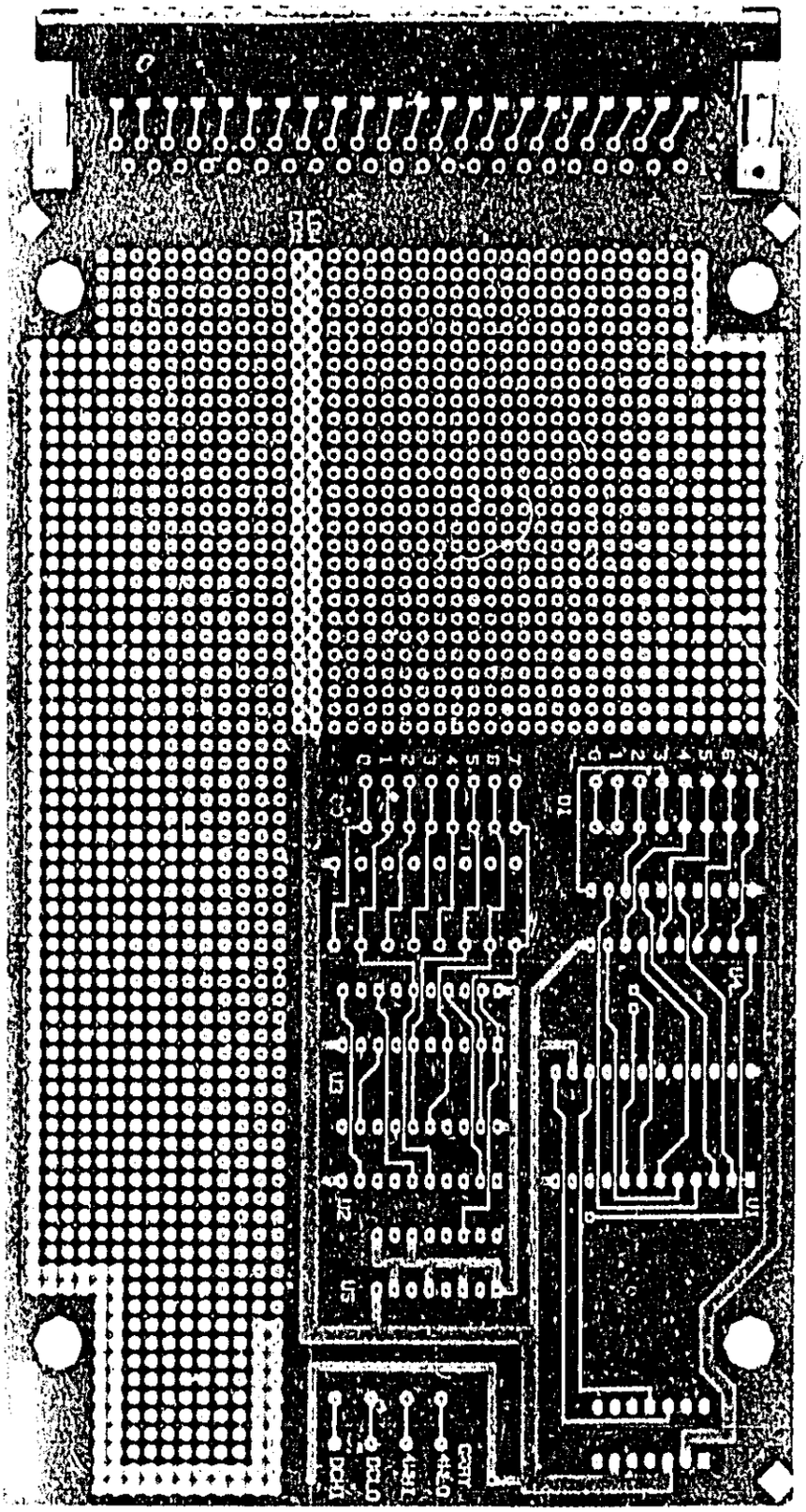


U4


TRW CINCH 251 22 30 261
U4
U3
U2
U1
J1
J2
J3
J4




TRW CINCH 251 22 30 261
U4
U3
U2
U1
REV A



# APPENDIX

# *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.

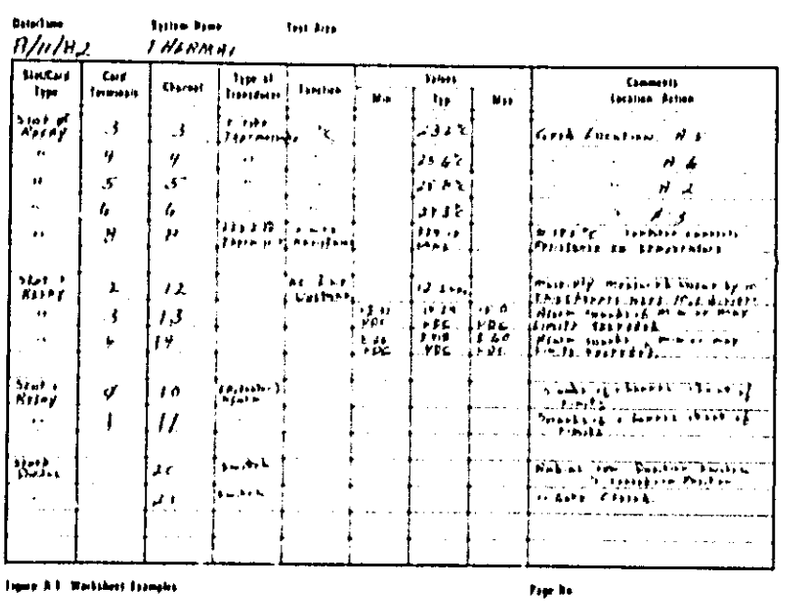


Figure A1. Worksheet Examples

# 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.

Date/Time: System Name: Test Area:

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

Date/Time: System Name: Test Area:

| Slot/Card Type | Card Terminals | Channel | Type of Transducer | Function | Values | | | Comments Location, Action |
|---|---|---|---|---|---|---|---|---|
| | | | | | Min | Typ | Max | |
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# *Appendix B*
# *HP-IL/HP-IB*

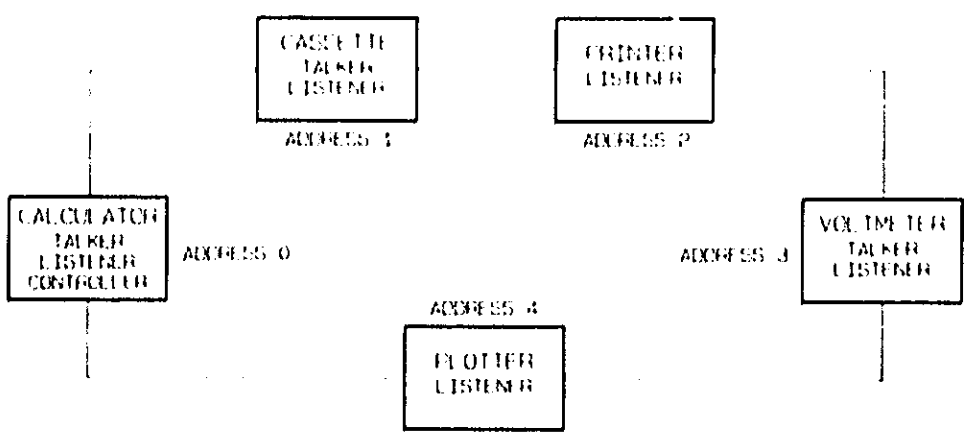
## Introduction

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

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.

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.

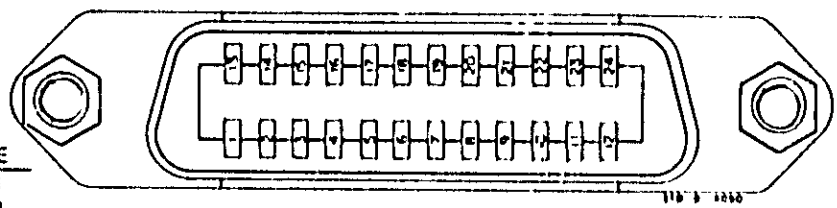
| | |
|---|---|
| R | The 3421A handshakes as a receiver. |
| D | Handshakes as a driver to the next device. |
| AH | Handshakes as an acceptor. |
| SH1 | Handshakes as a source. |
| T1,2, 3,4,6 | Basic Talker, send Status, send Device ID, send Accessory ID, Unaddressed as a talker when addressed as 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."

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.

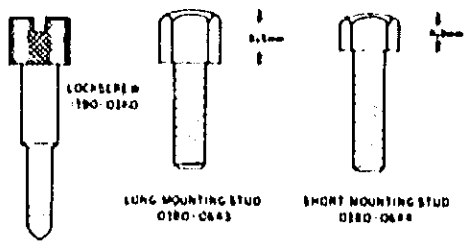


| PIN | LINE |
|---|---|
| 1 | DIO1 |
| 2 | DIO2 |
| 3 | DIO3 |
| 4 | DIO4 |
| 13 | DIO5 |
| 14 | DIO6 |
| 15 | DIO7 |
| 16 | DIO8 |
| 5 | EOI |
| 17 | REN |
| 6 | DAV |
| 7 | NRFD |
| 8 | NDAC |
| 9 | IFC |
| 10 | SRQ |
| 11 | ATN |
| 12 | SHIELD–CHASSIS GROUND |
| 18 | P/O TWISTED PAIR WITH PIN 6 |
| 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**

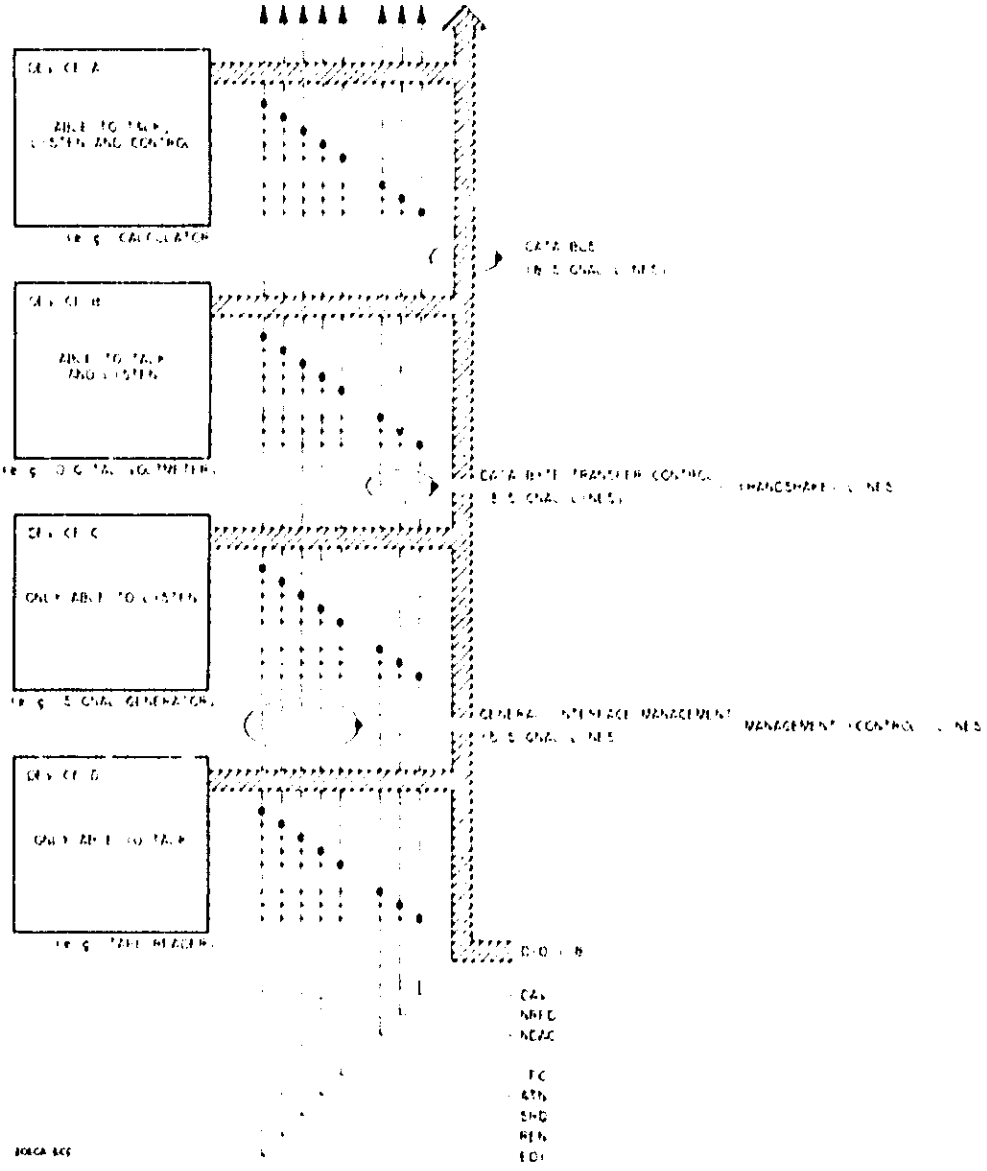
*The 3421A contains metric threaded HP-IB cable mounting studs as opposed to English threads. Metric threaded hp 10631A, B, or C HP-IB cable lockscrews must be used to secure the cable to the instrument. Identification of the two types of mounting studs and lockscrews is made by their color. English 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-



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

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.

- 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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# INDEX

# MANUAL CHANGES

# MANUAL CHANGES

-hp- MODEL 3421A

DATA ACQUISITION AND CONTROL UNIT

Manual Part Number 03421-90010

**CHANGE NO. 1. Applies to 44462As with ERC 2421 and Above.**

**Complete Manual.** Change all the 10 Channel Multiplexer Option references in the manual to Multiplexer/Actuator Option.

**Page 140, Heading: Channels.** Change the third paragraph to the following:

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

**Page 145, Heading: Voltage Measurements.** Change Channels 0 through 7 in the third sentence of the first paragraph to Channels 2 through 7.

**Page 154, Heading: Attenuators.** Change the second and third paragraphs to the following:

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

**Page 155, Heading: Attenuators.** Change Channels 0, 1 and 3 through 7 in the first sentence of the first paragraph to Channels 3 through 7.

**Page 2-18, Heading: Actuator/Multiplexer Jumpers.** Change the first two paragraphs and the first sentence of the third paragraph to the following:

Channels 0 and 1 on each multiplexer assembly can be configured as either actuators or as multiplexers. Several jumpers are provided on each channel for this conversion. The photograph below shows the location of the jumpers on older assemblies using soldered-in jumpers. The jumpers on the present assemblies are in the same location, except they are flying lead jumpers.

The diagram below show which jumpers need to be in place for the channels to be configured as actuators or multiplexers. The diagram applies for older assemblies that had soldered-in jumpers. For the present assemblies that use flying lead jumpers, refer to the assembly itself. Connect both H0 and L0 to their corresponding 'MUX' point to configure channel 0 as a multiplexer, or connect to 'ACT' to configure the channel as an actuator. Use H1 and L1 to configure channel 1.

The following diagram and chart show which jumpers need to be in place for channels 0 and 1 to be configured as actuators and which jumpers need to be inplace for channels 0 and 1 to be configured as multiplexers. The following diagram is for older assemblies. For the presen assemblies, use the information on the assembly itself to determine the configuration (see previous paragraph).

**Page 221, Heading: Attenuators.** Change the first three paragraphs under the heading as follows:

Provisions are made on the 44462A circuit board for attenuators to be installed on channels 2 through 7. On board provisions are not provided for attenuators on channels 0, 1, 8, and 9. An attenuator is composed of two resistors that act as a voltage divider. Consider the following diagram.

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

Channels 3 through 7 can all have attenuators built into their respective signal paths. An older 44462A assemblie. , channels 0 and 1 also had provisions to install attenuators, if the channels are configured as multiplexers. The following diagram shows how to install the attenuators. A package of seven pairs of resistors (-hp- part number 44469A) is available for use as attenuators. These resistors are the same values as those used in channel 2.

**CHANGE NO. 2. Applies to All Serial Numbers.**

**Page 188, Power Cords Figure.** Change the -hp- part number of the NEMA 5-15P power cable (last cable in the figure) from "8120-1521" to "8120-1378".