ADC71A

LIMITED WARRANTY

The ADC71A is warranted by Interface Instrument Corporation, against defects in materials and workmanship for one year from the date of original purchase. During the one year period, Interface Instrument Corp. will, at our option, repair or replace at no charge a defective product, provided you return the product, shipping prepaid, to our company headquarters.

This warranty does not apply if the product has been damaged by accident or misuse, or by excessive voltage, or as the result of service or modification not performed by Interface Instrument. No warranty is given regarding battery life.

No other express warranty is given. The repair or replacement of the product is your exclusive remedy. In no event shall Interface Instrument be liable for consequential damages.

This product is sold on the basis of specifications applicable at the time of manufacture. Interface Instrument shall have no obligation to modify or update products once sold.

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Chapter 1 - Introduction

The ADC71A is a 16 channel, $4\frac{1}{2}$ digit analog to digital converter that operates with either an HPIL equipped HP41C series programmable calculator or an HPIL equipped HP71B handheld BASIC computer to make a complete data aquisition processing system. It is intended for field, plant, or laboratory, where accuracy, reliability, and battery power are operational requirements.

The ADC71A can also be configured for up to 8 differential or 16 single-ended signals, and a combination of input types can be used if desired. Four software selected voltage ranges accomodate signals from many types of sensors, including thermocouples. On its most sensitive range, the ADC71A has a resolution of 2 microvolts.

Connecting input signals to the ADC71A is easy, using captive screw compression terminals. A thermistor, in thermal contact with the terminal block, provides the reference junction temperature for thermocouple compensation.

In addition to analog inputs, there are 8 optically isolated digital output lines. These are TTL/CMOS compatible, and can be used to control external circuits, instruments, or for process control. The optical isolation of these lines assures no interaction with the analog input signals.

1.1 Analog Inputs

The ADC71A has 16 analog inputs lines. These can be used as 16 single-ended inputs, 8 differential inputs, or a combination of single-ended and differential inputs. The input type is selected by software and wiring convention. Each single-ended input uses one input line, while each differential input uses two lines. Examples of possible input combinations are: 4 differential and 8 single-ended, 1 differential and 14 single-ended, or 7 differential and 2 single-ended. Note that the total number of input lines is limited to 16. Single-ended inputs share a common terminal. Differential inputs are isolated from each other, i.e. floating.

The choice between single-ended or differential input modes depends on the signal source. The differential mode is necessary when multiple inputs must be isolated from each other and when low level signals must be measured in the presence of common mode noise. Low level sensors, such as strain gauges and thermocouples should be measured in the differential mode. The single-ended mode can be used for multiple high level inputs that share a common ground return node. Amplified sensor outputs and thermistors can often be measured in the single-ended mode.

Reference junction compensation is available for thermocouple measurements. This is accomplished using a thermistor which measures the temperature of the input terminal block of the ADC71A. Compensation for any of the common thermocouple metals can then be implemented in software, using the program subroutines which have been supplied with this manual.

The full scale input voltage range is software programmable. The ranges are ±38 millivolts (mV), ±150 mV, ±600 mV, and ±2.4 volts. On the most sensitive range (±38mV), resolution is 2 microvolts, or approximately 0.05°C temperature resolution when using copper vs. Constantan (type T) thermocouples. The resolutions on the other ranges are 8, 32, and 128 microvolts, respectively.

1.2 Analog Conversion Rate

The ADC71A uses the dual slope, signal integrating technique of analog to digital conversion. The signal integration time is 50 milliseconds, which is exactly 3 periods at 60 Hz, and provides high rejection of 60 Hz noise. The total conversion time is 200 milliseconds, which implies a conversion rate of 5 samples/sec with an infinitely fast controller. A real controller such as the HP71B or HP41C reduces this ideal conversion rate because of the time required to send commands and receive data using HPIL. The actual maximum sampling rate using the HP71B is 3.8 samples/sec for a single input, and 3.0 samples/sec if multiple inputs are being scanned (see Section 3.6). Note that the sample rate per input is reduced by the number of inputs when multiple inputs are scanned. For example, with 6 inputs each input is measured once every 2 seconds. The HP41C is significantly slower than the HP71B. The maximum ADC71A sample rate with an HP41C controller is 1.7 samples/sec for a single input. In many applications either the HP41C or HP71B will provide sufficient controller speed.

1.3 HPIL

The required operational environment of the ADC71A is the Hewlett-Packard Interface Loop (HPIL). The loop controller can be an HP41C programmable calculator, an HP71B handheld computer, or any other computer having HPIL controller capability. Interconnection is made using standard HPIL receptacles and cables. Communication on the loop is unidirectional, with the HPIL receptacles labeled IN and OUT. The serial position number of a device on the loop (starting from the HPIL controller OUT receptacle or cable) is used as an address by the loop controller for specifying which device should respond to commands, send data, or receive data.

The HPIL controller determines the address of a specific device by searching for its "device ID". The "device ID" of the ADC71A is "HP82166A". If more than one ADC71A or an HP82166A HPIL Converter is on the loop, each must then be addressed according to its serial position. Normally, however, it is convenient to send instructions to the ADC71A under its identity as "HP82166A" rather than have to worry about its physical location on the loop.

The HPIL command vocabulary of the ADC71A is a subset of the I/O functions provided for the HP82401A (HP71B) and HP82160A (HP41C) HPIL modules. Users needing to fully customize their ADC71A data acquisition and control programs should become familiar with the HPIL instruction set of their controller. In many applications, however, the subroutines provided in chapter 3 (HP71B) and chapter 4 (HP41C) can be used to control the ADC71A.

Chapter 2 - Operating Instructions

This chapter provides general information on connecting the ADC71A to an HPIL controller, and using it to make voltage and temperature measurements and to generate digital output. Both hardware and software considerations are discussed, but specific software subroutines are listed in Chapters 3 (HP71B) and 4 (HP41C).

2.1 Voltage Measurement

The ADC71A can measure signal voltages up to 2.4 volts, and as small as 2 microvolts, with the voltage range being selected through commands from the loop controller. As many as 16 single-ended or 8 differential input channels can be scanned. Channel selection is also commanded by the controller. Connection of signal voltages to the ADC71A is made at a terminal block on the rear panel. This block is covered by an access plate. The access plate is provided primarily to assure temperature uniformity of the terminals when making thermocouple measurements.

The terminal block has 26 attachment points. These points will accept wire guages up to #18 AWG. They are labeled as follows:

G 0 8 G 1 9 G 2 10 G 3 11 C C 4 12 G 5 13 G 6 14 G 7 15 G

The numbered terminals are used for signal inputs. Differential signals are connected to adjacent terminal pairs (0-8, 1-9, etc.). Single-ended signals are connected between the desired channel number and the common terminal "C". The two "C" terminals are electrically identical. This node is shared by all single-ended inputs. The ground terminals "G" are for connecting shields, when used, and should not be connected to the ground nodes of other equipment. The input wiring scheme is shown below:

Signal Pair	Single-Ended Inputs	Differential Inputs
input high	terminal 0 thru 15	terminal 0 thru 7
input low	common terminal "C"	terminal 8 thru 15

Shielded pair input cabling is recommended when making measurements in noisy locations, or when the input cables are long. When using shielded cable, the shield is connected to the "G" terminal nearest the input terminals used. To avoid introducing a ground loop in the shield circuit, be sure that the shield does not make connection at any other point, i.e. no connection to shield at the sensor end, nor any possibility of inadvertent contact, such as via connector shells. Connect the shield at one, and only one, place: "G".

2.2 Thermocouple Temperature Measurement

The excellent sensitivity of the ADC71A makes theromocouple temperature measurement practical. This capability is enhanced because of the ADC71A's built-in reference junction. Thermocouple measurements utilize the differential input configuration, internally measured input terminal temperature and the ±38 millivolt range. Convention dictates that the first named metal (or alloy) is connected to the positive input terminal.

Voltage to temperature algorithms for two types of thermocouples are provided with this manual. One is for the commonly used type "T" thermocouple materials (copper vs. Constantan). This type has high temperature sensitivity (approx. 40 microvolts per °C) and accuracy (approx. 1°C), and is used in noncorrosive environments over a range of -160°C to +400°C. The other is type "R" (platinum vs. platinum - 13% rhodium). Type R is useful up to 1500°C with good accuracy (approx. 1°C), although lower in sensitivity (approx. 10 microvolts per °C). It can tolerate corrosive environments. Algorithms for other thermocouple types can be developed from published tables by using curve fitting software to generate a polynomial equation of the desired accuracy.

To realize the advantages of thermocouples it is necessary to insure that certain operating rules are followed. These are best explained in the context of a short review of how thermocouples work. Whenever two different metals make electrical contact, a voltage is produced. The magnitude of this voltage is also a function of the temperature of the contact point. This thermoelectric phenomenon is called the Seebeck effect. The Seebeck effect for certain metals or metal alloy combinations is well documented and provides the basis for thermocouple temperature measurements.

The Seebeck effect also occurs at the input terminals of the instrument used to measure the thermocouple voltage. These two additional junctions generate temperature dependent Seebeck voltages which add to the Seebeck voltage of the "sensing" thermocouple junction, where a temperature measurement is wanted. So, instead of having only one Seebeck junction, there are three. In order to determine the temperature of the thermocouple sensor, it is necessary to know, and to compensate for, the temperature at the datalogger input terminals.

Thermocouple compensation is usually accomplished using the reference junction technique. Historically this is done using an ice bath to stabilize the temperature of the reference junction at 0°C. The National Bureau of Standards thermocouple tables assume a 0°C reference junction. The ADC71A eliminates the need for an ice bath, by providing an internal thermistor to measure the temperature of the input terminal block. This allows the implementation of thermocouple compensation in software.

The measurement procedure, or measurement algorithm, for thermocouples requires several operations,

a) Measure the reference junction thermistor temperature.

c) Use this temperature to compute the Seebeck voltage that the particular thermocouple materials being used would produce at that temperature, if referenced against an ice bath. This voltage corresponds to the reference junction's output relative to its output at 0°C.

d) Measure the input voltage from the thermocouple sensor. The thermocouple is connected to differential input terminals according to the following convention:

Type	Input High	Input Low
E	Chromel	Constantan
J	iron	Constantan
K	Chromel	Alumel
R	platinum - 13% rhodium	platinum
S	platinum - 10% rhodium	platinum
T	copper	Constantan

e) Subtract the equivalent "ice point" voltage of the reference junction (c) from the measured thermocouple sensor voltage (d).

f) Convert this net thermocouple voltage to temperature using the polynomial equation appropriate to the thermocouple type and temperature range of interest.

This rather involved procedure is easily implemented in software using the ADC71A and the HP71B or HP41C. Sections 3.2 and 4.2 contain subroutines for this purpose.

2.3 Input Overload

The ADC71A changes input ranges by changing the gain of a programmable gain amplifier, which uses three 7652 chopper stabilized CMOS op-amps. These op-amps have excellent offset (5 μV) and drift (.05 μV/°C) performance, but if the chopper stabilization circuitry staturates due to an input overload, it can take as long as 3 seconds (depending on the magnitude and time duration of the overload) to recover. There are three major types of input overload: power on, excessive input voltage, and input scanning. When the ADC71A is initially turned on, either with the front panel switch, or under software control, the amplifier should allowed to stabilize for 3 seconds prior to use. An alternate approach is to measure offset voltage (see Table 2.2) in a continous loop until it reaches an acceptable value. Then real data collection can begin. This will usually be faster than the fixed 3 second delay. If the input voltage to the ADC71A exceeds full scale by more than about 10%, an overload will also occur. In most applications, overloads of this type should be prevented by choosing the correct input range. The ADC71A does provide overrange indication, however, which makes it possible to design software to detect excessive input voltage and take appropriate action (such as switching to a larger input range and entering an offset measurement recovery loop). Overrange indication on the ADC71A is provided by a raw data output of ±22222 (full scale is ±19999).

Input overload can also occur when the ADC71A is used to scan several inputs with different input ranges. This type of overload can be prevented by correct design of the scanning software. A .01 µf noise filter capacitor is located at the input to the programmable gain amplifier. When the ADC71A is switched from a large input voltage, say 2 volts on the ±2.4 volt range, to a small input voltage, say 1 millivolt on the ±38 millivolt, two things happen at the same time. The amplifier gain is switched from 1 to 64, and the amplifier input is connected to the new input channel. The problem is that the voltage on the .01 µf capacitor does not change to the new lower value immediately, and for a few milliseconds (depending on the source resistance) the amplifier input voltage greatly exceeds the 38 millivolt input range, causing the op-amp chopper circuitry to saturate. Recovery time is much less than the 3 second maximum due to the brief duration of the input overload, but recovery is not fast enough to prevent an error in the next reading. The recommended solution is to discharge the .01 µf capacitor with the amplifier in its lowest gain setting, before switching to the new channel. This is easily done using the statement,

```
OUTPUT :P ;CHR$(108);     (with the HP71B)
```

This connects both amplifier inputs to ground (see Table 2.2 in the manual) with the input range set to ±2.4 volts to prevent an overload. When the ADC71A is subsequently switched to the low level input, the residual charge from the previous channel will be gone.

2.4 HPIL

HPIL is a low power serial digital communications interface developed by the Hewlett-Packard Company. The interconnected devices are chained together, sharing a single pair cable around one loop. Hence the name Hewlett-Packard Interface Loop. HPIL is available for many HP computers, including the HP41C series programmable caculators, the HP71B handheld computer, the HP75, and the HP110 portable MSDOS computer.

HPIL is used by the ADC71A to receive commands from the computer and to send data to the computer. The computer must be equipped with the appropriate HPIL module; for the HP71B, this will be an HP82401A; for HP41C series calculators, an HP82160A.

HPIL interconnections are straight forward. HPIL cables are simply plugged in. The 2 connectors on each device are shaped to preclude any possibilty of misconnection.

The ADC71A will identify itself as an "HP82166A" HPIL Converter, and can receive commands according to that address. If more than one "HP82166A" device is on the loop, communications will need to be made with regard to the device's physical location along the loop.

HPIL can be used to place the ADC71A in its "standby" power mode, and restore to its "on" power mode (see Sections 3.4 and 4.4). This software technique is useful in conserving battery power. Placing the ADC71A in its "standby" mode is evidenced by the POWER LED being extinguished.

2.5 Analog Command

The ADC71A has sixteen external and three internal (offset voltage, reference junction thermistor, and battery voltage) inputs. The desired input is selected with the analog command byte, which also specifies the input range and mode (differential or single-ended). The command byte must be sent to the ADC71A by the HPIL controller as a single character, with no carriage return, linefeed termination sequence. This is done on the HP71B with a semicolon (;) at the end of the OUTPUT statement, and on the HP41C by setting flag 17.

The analog command byte is composed of several independent parameters. P1(HP71B) or R04(HP41C) determines the input signal range of the ADC71A.

P1 or R04	Full Scale Range
0	±38 millivolts
1	±150 millivolts
2	±600 millivolts
3	±2.4 volts

Table 2.1 - Analog Input Range

P2 or R05 is used to select between differential and single-ended input configurations. P3 or R06 specifies the desired analog input channel. Table 2.2 shows the relationship between these variables and the selected analog input. See section 3.1 (HP71B) or 4.1 (HP41C) for the actual software to send the analog command byte to the ADC71A.

P2/R05	P3/R06	Function	+Input	-Input
0	0	differential	0	8
0	1	differential	1	9
0	2	differential	2	10
0	3	differential	3	11
0	4	differential	4	12
0	5	differential	5	13
0	6	differential	6	14
0	7	differential	7	15
0	8	disable	-	-
0	12	offset	G	G
0	13	thermistor	T	G
0	14	battery	B	G
1	0	single-ended	0	C
1	1	single-ended	1	C
1	2	single-ended	2	C
1	3	single-ended	3	C
1	4	single-ended	4	C
1	5	single-ended	5	C
1	6	single-ended	6	C
1	7	single-ended	7	C
1	8	single-ended	8	C
1	9	single-ended	9	C
1	10	single-ended	10	C
1	11	single-ended	11	C
1	12	single-ended	12	C
1	13	single-ended	13	C
1	14	single-ended	14	C
1	15	single-ended	15	C

Table 2.2 - Analog Input Configuration

2.6 Digital Output

Eight TTL/CMOS compatible digital outputs and one strobe are provided by the ADC71A. All of these outputs are optically isolated from the circuitry of the ADC71A. This guarantees no interaction between the analog input circuitry and digital output circuitry. The major reason for isolation is the avoidance of ground loops which might otherwise destroy analog signal measurement integrity.

Access to the digital outputs is through a DB15P connector mounted on the rear panel of the ADC71A. The pinout for this connector is,

pin 1	:	data bit 0 (LSB)
2	:	data bit 1
3	:	data bit 2
4	:	data bit 3
5	:	data bit 4
6	:	data bit 5
7	:	data bit 6
8	:	data bit 7 (MSB)
9	:	strobe
10	:	signal and power ground
11	:	no connection
12	:	relay contact
13	:	relay contact
14	:	no connection
15	:	power (+5 volts @ 5 ma)

Reading the data on any of the digital ouputs requires a +5 volt supply connected between pins 15 and 10. The output data is available on pins 1 thru 8 and can drive one LS TTL load or CMOS logic. The strobe output is a negative going pulse. The 0 to 1 transition of the strobe pulse can be used to load the output data into a register. Provision is also made for power gating external equipment with the relay contacts, which close when the ADC71A is in the "on" power state (see Section 2.6).

Digital output instructions change the state of one nibble (4 bits) at a time. To set both the lower nibble (bits 0 thru 3) and the upper nibble (bits 4 thru 7) requires two instructions from the controller. The data nibble to be transferred is placed in the lowest 4 bits of the command byte from the controller. If bit 4 of this byte is 0, the data is placed in the lower nibble of the digital output byte. If bit 5 of this byte is low 0, the data is placed in the upper nibble of the digital output byte. Bit 6 of the command byte is used to enable the strobe, which occurs when bit 6 is 1. The digital command byte is defined as follows,

bit 0	:	data bit 0
1	:	data bit 1
2	:	data bit 2
3	:	data bit 3
4	:	low nibble enable (active low)
5	:	high nibble enable (active low)
6	:	strobe enable (active high)
7	:	1 (indicates digital output command)

The optical isolators used in the digital output interface use a substantial amount of power when the output data lines are in the logic 0 state. To increase battery life, set the digital output to 11111111 when it is not being used. This can be done with a single command by enabling both the high and low nibbles at the same time (see Sections 3.3 and 4.3).

2.7 Power

The ADC71A is equipped with a Gates 2.5 ampere-hour sealed lead acid rechargable battery. The ADC71A obtains its operating power from this battery except when the battery is being charged. The built-in battery charger has sufficient capacity to power the ADC71A while the battery is being charged. WARNING! DO NOT charge the battery inside a gas tight container.

The battery can operate the ADC71A for 20 hours between charging cycles. Battery lifetime is a minimum of 200 charge-discharge cycles. Alternatively, the battery can be maintained on float charge, using the AC power adapter. In this mode, the battery is used only during periods of AC power outage, and battery lifetime is greatly extended. The battery charger can be powered from the AC adapter. Or an external DC source, such as an automotive battery, can be used. Charging time is 6 hours.

There are 3 power states, controlled by both the power switch (ON/OFF) and HPIL. When the power switch is ON, the HPIL controller can switch the ADC71A between the "on" and "standby" power states. When the ADC71A is "on", the POWER LED indicator will be lit. This LED will flash when the internal battery voltage drops below about 5.7 volts. The ADC71A will continue to operate reliably down to a battery voltage of 5.6 volts, however the flashing serves as a warning that the battery needs charging. Do not allow the battery to discharge completely. This can destroy the ability of the battery to accept a charge. The ADC71A should be stored with its battery in a fully charged condition.

The ADC71A battery charger has two modes. The fast charge mode will restore charge to the battery in 6 hours. In this mode the CHARGE LED will be lit. When battery capacity is restored, the charger switches to a float charge mode. At this time the CHARGE LED will go out. The ADC71A can be left in this float charge mode indefinitely. The battery is maintained at full charge, ready to operate the ADC71A on demand. The power switch setting has no control over the battery charger.

The battery charger can be powered from the AC adapter supplied with the ADC71A or from an external DC power source (10 to 13 volts DC at 1 ampere). This can be an automotive battery, or a transformer operated DC power supply. Polarity of the external DC supply is important. The power connector on the ADC71A will accept a standard 5.5 mm by 2.5 mm diameter coaxial power plug. The center conductor of this plug should be connected to the positive terminal of the external supply.

Note that automotive batteries and other conventional lead acid battteries emit corrosive fumes which can damage electronic components. Never place the ADC71A in the same enclosure with an automotive battery.

The 1 ampere fuse, mounted on the rear panel of the ADC71A, serves two purposes. It will blow if the polarity of the external DC supply is reversed, or if the applied voltage exceeds 16 volts. Be sure to correct the cause of the blown fuse before replacing the fuse.

When in the fast charge mode there will be extra heat dissipated by the internal battery charger. Temperature gradients created inside the ADC71A may result in analog measurement inaccuracies. Thus, when critical low level measurements are anticipated, it is best to begin with a fully charged battery, and either maintain it on float charge during the measurement period or limit the measurement period to 20 hours. This is particularly important for thermocouple measurements, since accurate reference junction compensation requires a uniform temperature across the input terminal block.

The ADC71A battery should be replaced only with a Gates Energy Products part number 0819-0012. This can be obtained from an industrial battery distributor or from Interface Instrument Corp.

Chapter 3 - HP71B Programming

This chapter describes how to use the HP71B to control the operation of the ADC71A. Subroutines are provided for voltage measurement, temperature measurement, and digital output. These routines use a consistent set of variables, all beginning with the letter "P" (see Table 3.1). It is important that these variable names be reserved for ADC71A use only.

The HP71B must be configured properly for the ADC71A subroutines to function. The arrays P4 and P8 must be declared using the following statements,

```
OPTION BASE 0
REAL P4(3)
REAL P8(11)
```

HP71B flags -21, -22, -23, and -24 affect HPIL operations. Flag -23 must be clear for the ADC71A subroutines to function, and for most applications, all four flags should be clear. Note that these flags are automatically cleared when the HP71B is initially powered up or recovers from a "memory lost" condition. Thus unless these flags have been specifically set, they will be clear. Otherwise use the CFLAG statement to clear them. Finally, the ADC71A must be assigned an HPIL address using the following statements,

```
RESTORE IO
P=DEVADDR("HP82166A")
```

If another ADC71A or an HP82166A HPIL Converter is also on the HPIL loop, the ADC71A must be addressed by its sequential position on the loop, starting from the HPIL OUT connector on the HP71B.

P	ADC71A HPIL loop address
P0	measured voltage (volts)
P1	analog input range (see Table 2.1)
P2	analog mode (see Table 2.2)
P3	analog input channel (see Table 2.2)
P4	calibration constant array (see Appendix B)
P5	reference junction temperature (°C)
P6	reference junction "ice point" voltage
P7	thermocouple temperature (°C)
P8	thermocouple linearization constants
P9	digital output byte (0 to 255)

Table 3.1 - ADC71A Reserved Variables

3.1 Voltage Measurement

To make a voltage measurement, the ADC71A must first receive a single character analog command specifying the input range, mode (differential or single-ended), and channel number. This command is specified using variables P1, P2, and P3 (see Section 2.5 and Tables 2.1 and 2.2). Following the analog command, a voltage measurement can be made using the HP71B keywords TRIGGER, which initiates the measurement, and ENTER, which transfers the data from the ADC71A to the HP71B.

Three subroutines are given for voltage measurement. These subroutines assume that the ADC71A is at HPIL loop address P; that P1, P2, and P3 have been correctly specified; and that array P4 contains the calibration constants of the ADC71A (see Appendix B). Subroutine 9000 transmits the analog command to the ADC71A, but does not make a voltage measurement. Subroutine 9100 makes a voltage measurement, assuming that the ADC71A has already received the correct analog command. Subroutine 9200 performs both the analog command and voltage measurement functions. Subroutines 9100 and 9200 use P0 to store the result. Applications making repeated measurements of a single channel, should use subroutines 9000 and 9100. The analog command can be sent once using subroutine 9000, and the repeated measurements can be made using subroutine 9100. Applications which scan two or more channels should use subroutine 9200.

```
9000 ! ADC71A Analog Command Subroutine
9010 OUTPUT :P ;CHR$(32*P1+16*P2+P3);
9020 RETURN

9100 ! ADC71A Voltage Measurement Subroutine
9110 TRIGGER :P
9120 ENTER :P ;P0
9130 P0=P0*P4(P1)
9140 RETURN
```

```
9200 ! ADC71A Command & Measurement Subroutine
9210 OUTPUT :P ;CHR$(32*P1+16*P2+P3);
9220 WAIT .02
9230 TRIGGER :P
9240 ENTER :P ;P0
9250 P0=P0*P4(P1)
9260 RETURN
```

3.2 Temperature Measurement

Thermocouple temperature measurement (see Section 2.2) requires the following steps,

a) Measure the reference junction temperature and convert it to the equivalent "ice point" voltage.

b) Measure the thermocouple voltage.

c) Calculate the thermocouple temperature using the results of "a" and "b".

Step "b" can be accomplished with subroutine 9200 in Section 3.1. Be sure to specify P1, P2, and P3 before calling subroutine 9200. Thermocouple measurements should be made using the 40 millivolt range (P1=0) and the differential mode (P2=0). Subroutine 9300 performs step "a". P5 is the resulting reference junction temperature (°C), and P6 is the reference junction "ice point" voltage. Subroutine 9400 performs step "c", assuming that the thermocouple voltage measured in step "b" is still stored in P0. P7 is the calculated thermocouple temperature (°C). Subroutines 9300 and 9400 use the linearization constants in array P8. These constants depend on the type of thermocouple wire used. Table 3.2 lists the correct values for type T (-160 to +400°C), type J (0 to +760°C), and type R (0 to +1000°C). The constants in array P8 must be defined before calling either subroutine 9300 or 9400.

	type T	type J	type R
P8(0)	0.10086091	-.048868252	0.263632917
P8(1)	25727.94369	19873.14503	179075.491
P8(2)	-767345.8295	-218614.5353	-48840341.37
P8(3)	78025595.81	11569199.78	1.90002E10
P8(4)	-9247486589	-264917531.4	-4.82704E12
P8(5)	6.97688E11	2018441314	7.62091E14
P8(6)	-2.66192E13	0	-7.20026E16
P8(7)	3.94078E14	0	3.71496E18
P8(8)	0	0	-8.03104E19
P8(9)	3.8664E-5	5.03674E-5	5.28E-6
P8(10)	3.96E-8	3.03E-8	1.48E-8
P8(11)	2.14E-11	-7.48E-11	-3.824E-11

Table 3.2 - Thermocouple Linearization Constants

```
9300 ! ADC71A Reference Junction Subroutine
9310 OUTPUT :P ;CHR$(109);
9320 WAIT .02
9330 TRIGGER :P
9340 ENTER :P ;P5
9350 P5=4020*P5/(9999-P5)
9360 P5=1/(.001467+2.3844E-4*LN(P5)+1.008E-7*LN(P5)^3)-273.15
9370 P6=P5*(P8(9)+P5*(P8(10)+P5*P8(11)))
9380 RETURN

9400 ! ADC71A Thermocouple Temperature Subroutine
9410 P7=P0+P6
9420 P7=P8(0)+P7*(P8(1)+P7*(P8(2)+P7*(P8(3)+P7*(P8(4)+
     P7*(P8(5)+P7*(P8(6)+P7*(P8(7)+P7*P8(8))))))))
9430 RETURN
```

3.3 Digital Output

Subroutine 9900 sends the 8 bit value (0 to 255) of P9 to the ADC71A digital output port. A negative going pulse on the strobe line (pin 9) signals the presence of new data. For further information on using the digital output, see Section 2.6. Note that due to the optical isolation, the output lines use power when they are in the logic "0" state. To reduce power consumption, set the digital output data to 255. This can be done using subroutine 9900, or by using the single statement,

```
OUTPUT :P ;CHR$(207);
```

```
9900 ! ADC71A Digital Output Subroutine
9910 OUTPUT :P ;CHR$(MOD(P9,16)+160); ! low nibble
9920 OUTPUT :P ;CHR$(P9 DIV 16+208); ! high nibble & strobe
9930 RETURN
```

3.4 Power Control

One of the important features of the ADC71A is its ability to switch between the "on" and "standby" power modes under program control (see Section 2.7). Since the battery current drain is only .3 ma in the "standby" power mode, this significantly increases battery life for applications that do not require the ADC71A to be on continuously. To put the ADC71A in the "standby" power mode, use the statement,

```
SEND LPD
```

To exit the "standby" power mode, use the statement,

```
RESTORE IO
```

If the HP71B flags -21 and -24 are both clear, an alternative power control technique is possible. The ADC71A will enter the "standby" power mode automatically when the HP71B is turned off, either manually or under program control using the BYE or OFF keywords. The ADC71A will exit the "standby" power mode automatically when the HP71B is turned on, either manually or with a previously executed ON TIMER statement (if BYE was used to turn off the HP71B).

The ON/OFF switch on the front panel of the ADC71A must be ON in order to use the power control techniques discussed above. The relay contacts (pins 12 and 13 of the DB15P connector on the ADC71A rear panel) will be closed when the ADC71A is in the "on" power state, and will be open when the ADC71A is in the "standby" power state. These relay contacts can be used to turn non-HPIL equipment on and off under program control along with the ADC71A.

The ADC71A can measure its own battery voltage. Since the ADC71A requires a battery voltage of at least 5.6 volts (the POWER LED starts to flash at about 5.7 volts) to achieve its specified accuracy, this feature can be used by data aquisition programs to determine the validity of measured data. The battery is measured using the ±2.4 volt range (P1=3), differential mode (P2=0), and channel 14 (P3=14). Since the battery voltage is larger than 2.4 volts, a 4:1 attenuator located inside the ADC71A is used to make this measurement. The measured voltage must therefore be multipied by 4 to yield the actual battery voltage. The following statements will store the battery voltage as variable P0,

```
P1=3
P2=0
P3=14
GOSUB 9200
P0=4*P0
```

3.5 Digital Voltmeter Program Example

This section presents a simple program using the ADC71A as a digital voltmeter. It prompts the user for range, mode, and channel information (respond with P1 from Table 2.1 and P2 & P3 from Table 2.2), and then makes repeated measurements of the selected channel, displaying the result on the HP71B display. Lines 1010 thru 1060 declare and define the calibration constant array. Be sure to use the actual calibration constants for your ADC71A (see Appendix B). Lines 1090 and 1100 address the HPIL loop and determine the ADC71A loop address. Lines 1120 thru 1140 prompt the user for the desired range, mode, and channel. Line 1150 formats the HP71B display for the specified range. Line 1160 calls subroutine 9000, which sends the analog command character to the ADC71A. Line 1170 calls subroutine 9100, which makes the voltage measurement. Lines 1180 and 1190 display the result. Line 1200 creates an infinite loop to make and display the specified measurement continuously. Note that subroutine 9000 is not included in the loop, since the analog command is constant. Use the ATTN key to exit the program.

```
1000 ! ADC71A Simple Digital Voltmeter
1010 OPTION BASE 0
1020 REAL P4(3)
1030 P4(0)=1.9000E-6
1040 P4(1)=7.6000E-6
1050 P4(2)=3.0000E-5
1060 P4(3)=1.2000E-4
1070 CFLAG -23
1080 INPUT "turn on ADC71A";Z$
1090 RESTORE IO
1100 P=DEVADDR("HP82166A")
1120 INPUT "range ? ";P1
1130 INPUT "mode ? ";P2
1140 INPUT "channel ? ";P3
1150 IF P1<2 THEN FIX(3-P1) ELSE FIX(4-P1)
1160 GOSUB 9000
1170 GOSUB 9100
1180 DISP 1000*P0;
1190 DISP " millivolts"
1200 GOTO 1170
9000 ! ADC71A Analog Command Subroutine
9010 OUTPUT :P ;CHR$(32*P1+16*P2+P3);
9020 RETURN
9100 ! ADC71A Voltage Measurement Subroutine
9110 TRIGGER :P
9120 ENTER :P ;P0
9130 P0=P0*P4(P1)
9140 RETURN
9999 END
```

3.6 High Speed Data Collection

The ADC71A is not intended for high speed sampling. It is optimized for accuracy, sensitivity, 60 Hz noise rejection, and portability, rather than speed. The maximum sample rate of the ADC71A, with an HP71B controller, is 3.8 samples/sec for a single channel and 3.0 samples/sec for multiple channels. To achieve these sample rates, the raw data output of the ADC71A must be stored directly to memory, without calibration or any other real time processing. Of course, any desired data processing may be performed on the raw data after data collection is complete. Note that the subroutines presented earlier in this chapter do process the measured data and will not achieve the maximum speed.

The program listed below may be used when speed is important. It prompts the user for the number of inputs (N0), the number of samples (N1), and the range, mode, and channel number of each input. The measured data is stored in a two dimensional integer array P9(M,N). Note that this program uses array OPTION BASE 0. Data element P9(0,0) corresponds to the first sample of the first input, and P9(N0-1,N1-1) corresponds to the last sample of the last input.

```
1000 ! ADC71A Fast Datalogger
1010 OPTION BASE 0
1020 CFLAG -23
1030 INPUT "turn on ADC71A";Z$
1040 RESTORE IO
1050 P=DEVADDR("HP82166A")
1060 FIX 0
1070 INPUT "# inputs ? ";N0
1080 INPUT "# samples ? ";N1
1090 DIM P$(N0-1)[1]
1100 INTEGER P9(N0-1,N1-1)
```

```
1110 FOR N=0 TO NO-1
1120 DISP STR$(N+1)[1,(N+6)/10];": range "; @ INPUT P1
1130 DISP STR$(N+1)[1,(N+6)/10];": mode "; @ INPUT P2
1140 DISP STR$(N+1)[1,(N+6)/10];": channel "; @ INPUT P3
1150 P$(N)=CHR$(32*P1+16*P2+P3)
1160 NEXT N
1170 DISP "measuring data"
1180 IF NO>1 THEN GOTO 1270
1190 OUTPUT :P ;P$(0);
1200 TO=TIME
1210 FOR N=0 to N1-1
1220 TRIGGER :P
1230 ENTER :P ;P9(0,N)
1240 NEXT N
1250 T1=TIME
1260 GOTO 1360
1270 TO=TIME
1280 FOR N=0 TO N1-1
1290 FOR M=0 TO NO-1
1300 OUTPUT :P ;P$(M);
1310 TRIGGER :P
1320 ENTER :P ;P9(M,N)
1330 NEXT M
1340 NEXT N
1350 T1=TIME
1360 DISP USING "D.D,' samples/sec'";NO*N1/(T1-TO)
1370 BEEP
1380 END
```

Chapter 4 - HP41C Programming

This chapter describes how to use the HP41C to control the operation of the ADC71A. Subroutines are provided for voltage measurement, temperature measurement, and digital output. These routines use HP41C registers 00 thru 22 if the ADC71A is used for temperature measurements, or 00 thru 06 if the ADC71A is used for voltage measurements only. Register assignments are shown in Table 4.1.

The HP41C must be configured properly for the ADC71A subroutines to function. The calibration constants (see Appendix B) must be stored in registers 00 thru 03, and the thermocouple linearization constants must be stored in registers 11 thru 22, before voltage and temperature measurements can be made. The HP41C should be placed in the "auto" HPIL mode, and the ADC71A designated as the "primary" device using the following instructions,

```
AUTOIO
"HP82166A"
FINDID
SELECT
```

If another ADC71A or an HP82166A HPIL Converter is also on the HPIL loop, the ADC71A must be addressed by its sequential position on the loop, starting from the HPIL OUT line (the line with the smallest connector) on the HP41C.

The subroutines listed in this chapter use the OUTXB function in the HP82183A Extended I/O Module. This is the preferred technique for sending analog commands and digital output to the ADC71A. Users who do not have an Extended I/O Module, but do have either an HP82180A Extended Functions Module or an HP41CX, can use the following instuctions to replace OUTXB,

```
CLA
XTOA
OUTA
```

Users with an HP41C or HP41CV who do not have either the Extended I/O Module or the Extended Functions Module, cannot use the ADC71A for digital output. The following instructions can be substituted for OUTXB to send analog commands to the ADC71A,

```
0
X<>Y
BLDSPEC
CLA
ARCL X
OUTA
```

Flag 17 must be set for either of the alternate instruction sequences listed above to function, and neither of them will work for differential inputs on channel 0 with the ±38 millivolt range (R04=R05=R06=0).

The ACCHR function can also be used in place of OUTXB. It will work for R04=R05=R06=0, but will not work for R04=3, R05=1, R06=14 (single-ended input on channel 14, ±2.4 volt range), and will not do digital output. Flags 15 and 16 must be clear, flag 21 must be set, and the HP41C must be in the "manual" HPIL mode (MANIO) for ACCHR to work properly with the ADC71A. The small slide switch located on the bottom of the HP82160A HPIL module should be set to the ENABLE position.

00	calibration constant for ±38 mv range
01	calibration constant for ±150 mv range
02	calibration constant for ±600 mv range
03	calibration constant for ±2.4 volt range
04	analog input range (see Table 2.1)
05	analog mode (see Table 2.2)
06	analog input channel (see Table 2.2)
07	reference junction temperature (°C)
08	reference junction "ice point" voltage
09	thermocouple temperature (°C)
10	thermocouple "ice point" voltage
11-22	thermocouple linearization constants

Table 4.1 - ADC71A Reserved Registers

4.1 Voltage Measurement

To make a voltage measurement, the ADC71A must first receive a single character analog command specifying the input range, mode (differential or single-ended), and channel number. This command is specified using registers 04, 05, and 06 (see Section 2.5 and Tables 2.1 and 2.2). Following the analog command, a voltage measurement can be made using the HP41C functions TRIGGER, which initiates the measurement, and IND, which transfers the data from the ADC71A to the HP41C.

Three subroutines are given for voltage measurement. These subroutines assume that the ADC71A is the "primary" HPIL device; that registers 04, 05, and 06 have been correctly specified; and that registers 00 thru 03 contain the calibration constants of the ADC71A (see Appendix B). Subroutine 90 transmits the analog command to the ADC71A, but does not make a voltage measurement. Subroutine 91 makes a voltage measurement, assuming that the ADC71A has already received the correct analog command. Subroutine 92 performs both the analog command and voltage measurement functions. Subroutines 91 and 92 use the X register to store the result. Applications making repeated measurements of a single channel, should use subroutines 90 and 91. The analog command can be sent once using subroutine 90, and the repeated measurements can be made using subroutine 91. Applications which scan two or more channels should use subroutine 92.

```
LBL 90
RCL 04
32
*
RCL 05
16
*
+
RCL 06
+
OUTXB
RTN
```

```
LBL 91
TRIGGER
RCL IND 04
IND
*
RTN
```

```
LBL 92          RCL 06
RCL 04          +
32              OUTXB
*               TRIGGER
RCL 05          RCL IND 04
16              IND
*               *
+               RTN
```

4.2 Temperature Measurement

Thermocouple temperature measurement (see Section 2.2) requires the following steps,

a) Measure the reference junction temperature and convert it to the equivalent "ice point" voltage.
b) Measure the thermocouple voltage.
c) Calculate the thermocouple temperature using the results of "a" and "b".

Step "b" can be accomplished with subroutine 92 in Section 4.1. Be sure to define registers 04, 05, and 06 before calling subroutine 92. Thermocouple measurements should be made using the 40 millivolt range (R04=0) and the differential mode (R05=0). Subroutine 93 performs step "a". The resulting reference junction temperature (°C) is stored in register 07, and the reference junction "ice point" voltage is stored in register 08. Subroutine 94 performs step "c", assuming that the thermocouple voltage measured in step "b" is still stored in the X register. The calculated thermocouple temperature (°C) is stored in register 09, and the thermocouple "ice point" voltage is stored in register 10. Subroutines 93 and 94 use the linearization constants in registers 11 thru 22. These constants depend on the type of thermocouple wire used. Table 4.2 lists the correct values for type T (-160 to +400°C), type J (0 to +760°C), and type R (0 to +1000°C). These registers must be correctly defined before calling either subroutine 93 or 94.

register	type T	type J	type R
11	0.10086091	-.048868252	0.26363291 7
12	25727.94369	19873.14503	179075.491
13	-767345.8295	-218614.5353	-48840341.37
14	78025595.81	11569199.78	1.90002E10
15	-9247486589	-264917531.4	-4.82704E12
16	6.97688E11	2018441314	7.62091E14
17	-2.66192E13	0	-7.20026E16
18	3.94078E14	0	3.71496E18
19	0	0	-8.03104E19
20	3.8664E-5	5.03674E-5	5.28E-6
21	3.96E-8	3.03E-8	1.48E-8
22	2.14E-11	-7.48E-11	-3.824E-11

Table 4.2 - Thermocouple Linearization Constants

```
LBL 93
109
OUTXB
TRIGGER
2.3844E-4
4020
IND
*
LAST X
9999
X<>Y
-
/
LN
*
LAST X
3
Y^X
1.008E-7
*
+
.001467
+
1/X
273.15
-
STO 07
RCL 22
*
RCL 21
+
RCL 07
*
RCL 20
+
RCL 07
*
STO 08
RTN
```

```
LBL 94
RCL 08
+
STO 10
RCL 19
*
RCL 18
+
RCL 10
*
RCL 17
+
RCL 10
*
RCL 16
+
RCL 10
*
RCL 15
+
RCL 10
*
RCL 14
+
RCL 10
*
RCL 13
+
RCL 10
*
RCL 12
+
RCL 10
*
RCL 11
+
STO 09
RTN
```

4.3 Digital Output

Subroutine 99 sends the 8 bit value (0 to 255) of the X register to the ADC71A digital output port. A negative going pulse on the strobe line (pin 9) signals the presence of new data. For further information on using the digital output, see Section 2.6. Note that due to the optical isolation, the output lines use power when they are in the logic "0" state. To reduce power consumption, set the digital output data to 255. This can be done using subroutine 99, or by using the statements,

```
207
OUTXB

LBL 99
ENTER
ENTER
16
MOD
160
+
OUTXB
RDN
16
/
208
+
OUTXB
RTN
```

4.4 Power Control

One of the important features of the ADC71A is its ability to switch between the "on" and "standby" power modes under program control (see Section 2.7). Since the battery current drain is only .3 ma in the "standby" power mode, this significantly increases battery life for applications that do not require the ADC71A to be on continuously. To put the ADC71A in the "standby" power mode, use the PWRDN function. To exit the "standby" power mode, use the PWRUP function.

The ON/OFF switch on the front panel of the ADC71A must be ON in order to use the power control technique discussed above. The relay contacts (pins 12 and 13 of the DB15P connector on the ADC71A rear panel) will be closed when the ADC71A is in the "on" power state, and will be open when the ADC71A is in the "standby" power state. These relay contacts can be used to turn non-HPIL equipment on and off under program control along with the ADC71A.

The ADC71A can measure its own battery voltage. Since the ADC71A requires a battery voltage of at least 5.6 volts (the POWER LED starts to flash at about 5.7 volts) to achieve its specified accuracy, this feature can be used by data aquisition programs to determine the validity of measured data. The battery is measured using the ±2.4 volt range (R04=3), differential mode (R05=0), and channel 14 (R06=14). Since the battery voltage is larger than 2.4 volts, a 4:1 attenuator located inside the ADC71A is used to make this measurement. The measured voltage must therefore be multipied by 4 to yield the actual battery voltage. The following instructions will leave the battery voltage in the X register,

```
3
STO 04
0
STO 05
14
STO 06
XEQ 92
4
*
```

4.5 Digital Voltmeter Program Example

This section presents a simple program using the ADC71A as a digital voltmeter. It prompts the user for range, mode, and channel information (respond with the desired values from Table 2.1 and Table 2.2), and then makes repeated measurements of the selected channel, displaying the result on the HP41C display. Lines 02 thru 09 define the calibration constant array. Be sure to use the actual calibration constants for your ADC71A (see Appendix B). Lines 12 thru 15 address the HPIL loop and determine the ADC71A loop address. Lines 16 thru 24 prompt the user for the desired range, mode, and channel. Lines 25 thru 32 format the HP71B display for the specified range. Line 35 calls subroutine 90, which sends the analog command character to the ADC71A. Line 37 calls subroutine 91, which makes the voltage measurement. Lines 40 thru 43 display the result. Line 44 creates an infinite loop to make and display the specified measurement continuously. Note that subroutine 90 is not included in the loop, since the analog command is constant. Use the R/S key to exit the program.

```
01  LBL DVM
02  1.9E-6
03  STO 00
04  7.6E-6
05  STO 01
06  3.0E-5
07  STO 02
08  1.2E-4
09  STO 03
10  "TURN ON ADC"
11  PROMPT
12  AUTOIO
13  "HP82166A"
14  FINDID
15  SELECT
16  "RANGE ?"
17  PROMPT
18  STO 04
19  "MODE ?"
20  PROMPT
21  STO 05
22  "CHANNEL ?"
23  PROMPT
24  STO 06
25  FIX 2
26  0
27  RCL 04
28  X=Y?
```

```
29  FIX 3
30  3
31  X=Y?
32  FIX 1
33  " MV"
34  ASTO 07
35  XEQ 90
36  LBL 01
37  XEQ 91
38  1000
39  *
40  CLA
41  ARCL X
42  ARCL 07
43  AVIEW
44  GTO 01
45  LBL 90
46  RCL 04
47  32
48  *
49  RCL 05
50  16
51  *
52  +
53  RCL 06
54  +
55  OUTXB
56  RTN
57  LBL 91
58  TRIGGER
59  RCL IND 04
60  IND
61  *
62  RTN
63  END
```

Chapter 5 - Calibration

The precision voltage reference used in the ADC71A has a typical long term stability of 20 ppm per 1000 hours of operation, making it an extremely stable device. In many applications, recalibration of the ADC71A will never be necessary. For applications requiring extreme accuracy, however, periodic calibration of the ADC71A is recommended. The proper calibration interval is a function of the application and each individual unit. Six months is suggested as the initial calibration interval. This may be adjusted based on the measured drift during the initial period.

Calibration of the ADC71A requires a voltage standard at least as accurate as the desired calibration accuracy. An accuracy of .005% or better is desirable. Suitable voltage calibration standards include models 343A, 515A, and 731B made by John Fluke Manufacturing Co. The basic calibration procedure consists of using the ADC71A to measure the known output of the voltage calibration standard. The calibration constant is then calculated as the ratio of the calibration voltage and the uncalibrated ADC71A output. This procedure is repeated for each of the four input ranges of the ADC71A. The initial calibration constants are listed in Appendix B. Note that there are no adjustments to make inside the ADC71A.

5.1 Calibration Program

This section contains an HP71B calibration program. A ThinkJet printer is required in addition to the HP71B and a calibration standard. The program prompts the user with the necessary calibration procedure instructions, and prints a calibration report on the ThinkJet. Ten measurements are made at each calibration voltage. For each of the four input ranges, the calibration report lists the average uncalibrated ADC71A output, the difference between the maximum and minimum readings (peak to peak system noise), and the calculated calibration constant. Offset voltage, battery voltage, and calibration temperature are also listed.

```
1000 ! ADC71A User Calibration Program for HP71B
1010 CFLAG -21 @ CFLAG -22
1020 CFLAG -23 @ CFLAG -24
1030 SCI 4
1040 OPTION BASE 0
1050 INTEGER D0,D1,N,P,P1,P2,P3,S
1060 REAL D,P0,P4(3),P5,V
1070 INPUT "turn on ADC71A";Z$
1080 INPUT "turn on ThinkJet";Z$
1090 INPUT "turn on calibrator";Z$
1100 RESTORE IO
1110 PRINTER IS PRINTER
1120 P=DEVADDR("HP82166A")
1130 OUTPUT :P ;CHR$(108);
1140 GOSUB 9100
1150 OUTPUT :P ;CHR$(207);
1160 INPUT "connect V+ to TERM 0";Z$
1170 INPUT "connect V- to TERM 8";Z$
1180 D$=DATE$[4,5]&"-"&DATE$[7,8]&"-"&DATE$[1,2]
1190 PRINT TAB(16);"ADC71A Calibration";TAB(60);D$;TAB(76);
1200 INPUT "serial number ? ";S
1210 PRINT USING "ZZZZ";S
1220 PRINT @ PRINT @ PRINT
1230 GOSUB 9300
1240 PRINT "calibration temperature";TAB(28);
1250 PRINT USING 'DD.D," C",6D.D," F"';P5;1.8*P5+32
1260 PRINT @ PRINT
1270 P2=0
1280 P3=0
1290 PRINT "input (mV)      output          constant"
1300 PRINT
1310 IMAGE 5D.DDD,6X,6D,X,DD,7X,K
1320 FOR P1=0 TO 3
1330 OUTPUT :P ;CHR$(108);
1340 IF P1=0 THEN INPUT "set Vin = .032 volts";Z$
1350 IF P1=1 THEN BEEP @ INPUT "set Vin = .125 volts";Z$
1360 IF P1=2 THEN BEEP @ INPUT "set Vin = .5 volts";Z$
1370 IF P1=3 THEN BEEP @ INPUT "set Vin = 2 volts";Z$
1380 GOSUB 9000
```

```
1390 INPUT "exact value Vin ? ";V
1400 GOSUB 2000
1410 P4(P1)=10*V/D
1420 PRINT USING 1310;1000*V;D/10;D1-D0;P4(P1)
1430 PRINT
1440 NEXT P1
1450 P1=0
1460 P3=12
1470 GOSUB 9000
1480 PRINT
1490 PRINT "offset voltage";TAB(20);
1500 GOSUB 2000
1510 PRINT USING 'DD,X,DD,4X,4D.D," microvolts"';
     D/10;D1-D0;100000*D*P4(0)
1520 P1=3
1530 P3=14
1540 GOSUB 9000
1550 PRINT @ PRINT
1560 PRINT "battery voltage";TAB(31);
1570 WAIT .05
1580 GOSUB 9100
1590 PRINT USING "DD.DDD";4*P0*P4(3)
1600 BEEP
1610 INPUT "turn off ADC71A";Z$
1620 STOP
2000 WAIT .05
2010 D=0
2020 D0=20000
2030 D1=-20000
2040 FOR N=1 TO 10
2050 GOSUB 9100
2060 DISP USING "DD,9D";N;P0
2070 D=D+P0
2080 D0=MIN(D0,P0)
2090 D1=MAX(D1,P0)
2100 NEXT N
2110 RETURN
```

```
9000 ! ADC71A Analog Command Subroutine
9010 OUTPUT :P ;CHR$(32*P1+16*P2+P3);
9020 RETURN
9100 ! ADC71A Voltage Measurement Subroutine
9110 TRIGGER :P
9120 ENTER :P ;P0
9130 RETURN
9300 ! ADC71A Reference Junction Subroutine
9310 OUTPUT :P ;CHR$(109);
9320 WAIT .02
9330 TRIGGER :P
9340 ENTER :P ;P5
9350 P5=4020*P5/(9999-P5)
9360 P5=1/(.001467+2.3844E-4*LN(P5)+1.008E-7*LN(P5)^3)-273.15
9370 RETURN
9900 ! ADC71A Digital Output Subroutine
9910 OUTPUT :P ;CHR$(MOD(P9,16)+160); ! low nibble
9920 OUTPUT :P ;CHR$(P9 DIV 16+208); ! high nibble & strobe
9930 RETURN
9999 END
```

Appendix A - ADC71A Specifications

Analog Input Characteristics

Range	Resolution	Impedance	Accuracy (23±5°C, 6 mo) ±(% reading + counts)
±38 mV	2 μV	100 meg Ω	.03 + 6
±150 mV	8 μV	100 meg Ω	.02 + 4
±600 mV	32 μV	100 meg Ω	.02 + 3
±2.4 V	128 μV	100 meg Ω	.02 + 2

Temperature Coefficient	±20 ppm/°C
Reference Junction Accuracy	±.5°C
Maximum Input Voltage	10 volts
Common Mode Voltage (between inputs)	200 volts
Operating Temperature Range	-20 to +60°C
Maximum Sampling Rate with HP71B	3.5 readings/sec
Power Requirements	
internal battery	100 ma (nominal)
	.3 ma (standby)
battery charger	
AC adapter	117 volts AC, 60 Hz
DC input	10 volts DC, 1 amp
Digital Output (8 data bits & strobe)	
logic levels	1 LS TTL or CMOS
power requirement	5 volts DC, 5 ma
Relay Contacts	
voltage	100 volts
current	.5 amps
power	10 watts
Size	6.2 x 8.6 x 2.0 inches