User manual for

PC-73

High Performance Analog I/O Boards for IBM PC, PC/XT, PC/AT, PS/2 Model 25 and 30 and compatible Computer Systems.

First edition.

June 1990

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Preface

This manual is written for users of the PC-73 thermocouple input board. It provides all information necessary to successfully program and operate the PC-73.

This manual assumes:

- That you have a basic knowledge of electronic circuitry and measurement techniques.
- That you are familiar with the host PC which you are using.
- That you are capable of writing your own programs.

The manual contains the following sections.

Chapter 1 - Introduction.

- Chapter 1 contains an overview of the PC-73 board.

Chapter 2 - Thermocouples.

- Chapter 2 provides a brief discussion of thermocouple fundamentals.

Chapter 3 - Architecture.

- Chapter 3 discusses the basic operation of the PC-73 board.

Chapter 4 - Configuration.

- Chapter 4 discusses the selection of various board parameters and the configuration of the board for various operating requirements.

Chapter 5 - Interconnection.

- Chapter 4 describes the connection of the PC-73 board to the host computer and to user inputs.

Chapter 6 - Register structure.

- Chapter 6 describes the register structure of the PC-73 board.

Chapter 7 - Software.

- Chapter 7 provides a full description of the driver software as well as the demonstration/calibration program supplied with the PC-73.

Chapter 8 - Calibration.

- Chapter 8 describes the procedures and equipment required to calibrate the PC-73 board.

Appendix A - Hardware Specifications.

- Appendix A provides complete electrical specifications for the PC-73 board.

Appendix B - Error limits.

- Appendix B discusses the typical performance of a PC-73 in combination with standard thermocouples.

Appendix B - Differences from previous versions.

- Appendix B discusses the differences between the current and previous software for the PC-73.

Appendix D - Problem Determination guide.

- Appendix D contains information which may help you if you are experiencing problems with your PC-73.

Table of Contents

Chapter 1

Introduction

1.1. Overview

The PC-73 is a low cost, high accuracy thermocouple measurement subsystem for the IBM PC, PC/XT, PC/AT, PS/2 model 25, PS/2 model 30 and compatible series of computers.

The PC-73 consists of two boards:

- A half-size PC plug-in, which contains an A/D converter, as well as signal conditioning and control components. This board plugs into the host PC.
- A screw-terminal/cold junction compensation board. This board, which is external to the PC, provides screw terminals for direct connection to thermocouples, as well as provision for cold-junction compensation. Connection to the PC plug-in board is via the supplied ribbon cable connector.

1.2. Features

The PC-73 can be plugged into any of the fully bussed slots in a PC/XT/AT or compatible computer.

1.2.1. A/D subsystem

The A/D subsystem's major component is a monolithic analog to digital converter, which accepts analog voltage inputs from thermocouples, and converts them into 12 bit digital codes.

This code is transmitted to the host processor, which processes it according to the software in use at the time.

The A/D section allows for 8 differential inputs, with a default input range of -40.95 to +40.95 mV (suitable for most thermocouples). In addition, input ranges of -4.095 to 4.095 V, -20.475 to 20.475 mV and -8.190 to 8.190 mV are also jumper selectable. Provision is also made for a separate cold-junction compensation input, with fixed range. Resolution is 12 bits plus sign. The output code is straight binary, with a separate sign bit.

Key specifications

- A/D resolution: 12 Bits + sign
- Nonlinearity: Less than +/-0.75 LSB
- A/D full scale input ranges: -40.95 to +40.95 mV, -4.095 to 4.095 V, -20.475 to 20.475 mV and -8.190 to 8.190 mV jumper selectable.
- Number of A/D inputs: 8 differential thermocouple inputs, one cold junction compensation input.
- A/D throughput rate: 30 Hz

1.2.2. Host interface

The PC-73 is accessed via I/O operations performed by the host processor. Of the 10 bit address received by the board, the most significant 8 bits select the board, and the least significant 2 bits select the register to be accessed.

The PC-73 occupies 4 byte locations. The base address of the PC-73 is switch selectable from 100H to 3FCH.

The PC-73 operates from the +5V, +12V and -12V lines of the PC bus.

1.3. Software support

Software support for the PC-73 is available in a variety of forms :

1.3.1. Supplied software

The software supplied with the PC-73 consist of two programs; the PC-73 driver software, and the PC-73 demonstration/calibration program.

1.3.1.1. Driver software

This consists of a set of real time device drivers for use with the PC-73 board. These device drivers are supplied in C and BASIC, and are callable from most compiled languages, including the following :

- Microsoft C version 5.1.
- Turbo C version 1.5.
- Microsoft QuickBasic version 4.5.

The driver software allows programers to control the PC-73 via high level function calls, so allowing users to write custom software without understanding the low level operation of the PC-73. Thermocouple linearisation for type J, K, E, T, B, R, S and N thermocouples is supported. Also included with the driver package is complete source code, in C and Basic, for the entire driver package. This allows advanced users to modify existing code, rather than having to start writing low level code from scratch.

1.3.1.2. LabWindows support

Included with the supplied driver is full support for LabWindows V1.2. This support is in the form of an instrument module, and its associated information files.

1.3.1.3. Demonstration/Calibration programs

The demonstration/calibration program is an application program, which combines the features of a thermocouple scanner and calibration program in one package. J, K, E, T, B, R, S and N type thermocouples are supported.

1.3.2. IoCalc

IoCalc is a spreadsheet program, with the ability to acquire, process and output data to and from analog and digital I/O devices in real-time. Not just an add-on for a spreadsheet program designed for business applications, IoCalc is a custom written real-time program, optimized for engineering and scientific users. Under OS/2, IoCalc provides full multi-tasking operation, allied with powerful inter-task communication capabilities.

Data is acquired directly into spreadsheet cells, processed, and in turn sent to output devices direct from spreadsheet cells.

The entire spreadsheet, or part of it, can be updated at fixed intervals, with timing resolution down to 10 milliseconds. Any section of the spreadsheet can also be logged to disk or printer at fixed intervals.

IoCalc can be used to implement virtually any process that can be represented mathematically. Sample spreadsheets supplied with IoCalc include : Control loops (PID and 'Bang-bang'), intelligent data loggers, digital filters, multi-channel multimeters, thermocouple compensation and oscillators.

Note that IoCalc must be purchased separately

1.3.2.1. Features

- True real-time, multi-tasking data processing
- Familiar user interface
- Can be used to implement control loops, data loggers, digital filters and more
- Menu driven, with context sensitive help.
- Either DOS or OS/2 protected mode operation.

1.3.2.2. Applications

- Process control
- Data logging
- Monitoring
- Automatic test

- Smart instrumentation
- Laboratory data collection
- Virtual instruments

1.4. Getting Started

If you want to get started quickly and have not changed any of the factory installed jumpers on the PC-73, here's what to do:

i. Install the PC-73 in your computer. (Chapter 3 provides brief instructions on this, but if you are not sure, it is better to get someone who is qualified to do this).

ii. Connect up a thermocouple to any (or all) of the input channels.

iii. Run the PC73.EXE program on the supplied disk. This program displays the temperature of the thermocouple on each channel, for most common thermocouples.

Chapter 2

Thermocouples

This chapter provides a brief introduction to thermocouples, and how to use them to their best advantage.

2.1. What are thermocouples?

A thermocouple is a temperature sensor that consists of two dissimilar metals joined at one end, as shown in figure 2.1. This joint is the junction, and produces a small thermoelectric voltage when the junction is heated. This thermoelectric voltage can be measured, and used to calculate the temperature of the junction.

Thermocouples have several significant advantages as temperature sensors :

- Low cost; all a thermocouple consists of is two metals in contact.
- Robust.
- Self powered.
- Wide temperature range.
- Can be optimized to suit various atmospheres and environmental conditions.

Thermocouples are also reasonably accurate, offering typical system accuracies of the order of 0.5 to 1 °C.

2.2. Cold junction compensation

When we attempt to measure the thermocouple voltage, a problem becomes apparent. As soon as we connect a voltmeter (or any other measuring device) to the thermocouple, we physically create three separate thermocouples (J1, J2 and J3). If both terminal blocks are at the same temperature, then the effects of the copper leads of the measuring instrument cancel out, effectively creating a single second thermocouple junction of the first type as the second. This is shown in figure 2.2. This

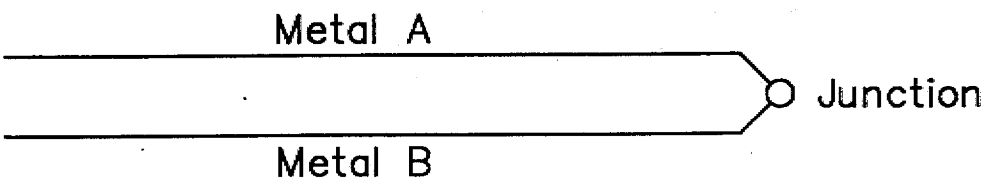

Figure 2.1. Thermocouple construction.

second junction is known as the "cold" or reference junction. Our measuring instrument now reads the difference between the cold junction, and the measuring junction.

The simplest and oldest method of dealing with this is to put the cold junction in an ice bath, so setting its temperature to zero. This removes the effect of the cold junction, but is very inconvenient.

A better technique is to measure the temperature of the cold junction and calculate the cold junction voltage. If we then add this to the measured voltage, we get the actual voltage of the measuring junction.

Example

Assume we have a K type thermocouple reading 23 mV, and the terminal block temperature is 21°C. What is the thermocouple temperature?

From thermocouple tables, at 21°C, a K type thermocouple produces 0.838 mV. This is then the cold junction temperature. We add this to the measured temperature, getting 23.838 mV. Once

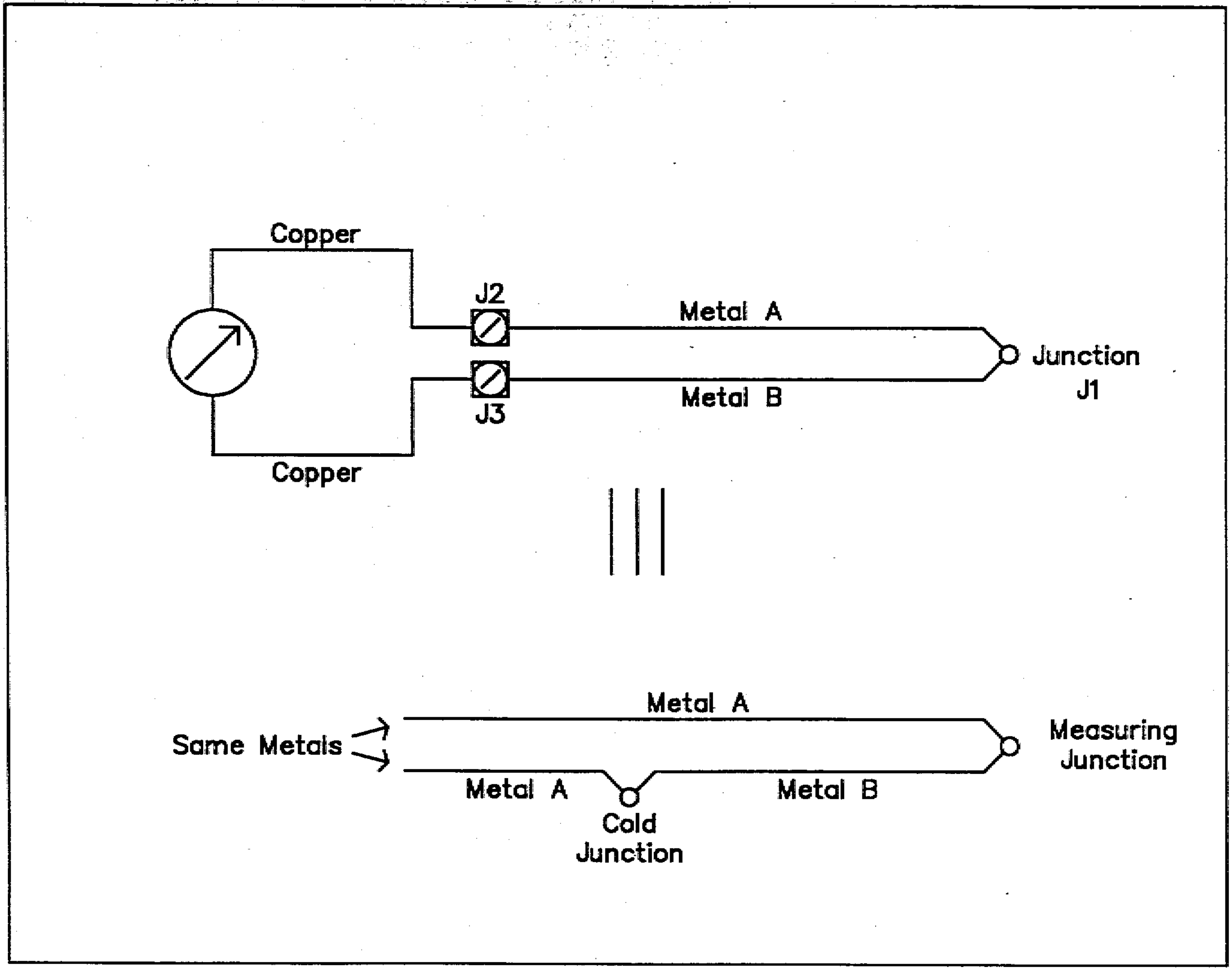

Figure 2.2. Thermocouple measurement.

again reading from the thermocouple tables, we find that this corresponds to almost exactly 575°C. This is the temperature of the measuring junction.

2.3. Thermocouple linearisation

In addition to requiring cold junction compensation, thermocouples are also highly nonlinear, and thus require linearisation. For example, a J type thermocouple has a thermal coefficient of 22 uV per °C at -200°C, but 64 uV per °C at 750°C.

For most purposes, some form of software based linearisation is used. Two techniques are in common use for linearisation :

- Look-up tables. With this technique, a table of temperature versus all possible measured voltages is stored, and the appropriate temperature obtained via an indexing operation. This is very fast, but requires large amounts of memory. Cold junction compensation is also difficult.

- Polynomial compensation. Using this technique, polynomial approximations are used to obtain temperature from voltage. The number of polynomial terms used depend on the temperature range, and the type of thermocouple. For example, type J thermocouples can be approximated to 0.1°C over 0 to 760°C with a fifth order polynomial, but a E type thermocouple requires a ninth order equation for only 0.5 degree accuracy.

  For wide temperature ranges, several lower order polynomials over narrower ranges are often used. For example, the PC-73 driver software uses three eighth order polynomials for voltage to temperature conversions. The range of each equation is optimized for each type of thermocouple. In addition, a second order polynomial is used to convert the cold junction temperature to a thermocouple voltage for compensation. The use of a second order polynomial is possible because the terminal block temperature varies only from 0 to 70°C.

2.4. Thermocouple standards

Thermocouple standards specify the voltage versus temperature characteristics, color codes, error limits and (not always) composition of standard thermocouples. There are five standards for thermocouples in general use. These are :

- NBS (Now NIST)/ANSI - American. The American NBS standard is currently the most widely used. Color codes are covered by ANSI. ANSI thermocouples all make use of red negative leg color codes. The PC-73 thermocouple linearisation equations are based on the NBS standard.
- BS - British. The British BS1843 standard makes use of blue negative leg color codes.
- DIN - German. DIN 43714 thermocouples all make use of red positive leg color coding.
- JIS - Japanese. JIS C 1610-1981 thermocouples all make use of red positive leg/white negative leg color coding.
- NF - French. NF C 42-323 thermocouples all make use of yellow positive leg color coding.

In general, most of the thermocouple standards are interchangeable in terms of voltage versus temperature curves. The only major exceptions to this are the DIN-J and DIN-T types.

You should however establish from your supplier to what standard your thermocouples conform, and check for any deviations from the standard that your measuring instrument supports.

Note
The PC-73 software makes use of NBS thermocouple linearisation.

Eight types of thermocouples are in general use in industry, in addition to a large number of special thermocouples. The thermocouples in common use can be divided into two groups: base metal thermocouples and noble metal thermocouples.

2.5. Base metal thermocouples

Base metal thermocouples are generally cheaper than noble metal thermocouples, and include the most commonly used types.

Base metal thermocouples (except the type N) do not have a specified composition, but may be any combination of metals that results in the appropriate voltage versus temperature curve. The base metal thermocouples are the following:

2.5.1. Type J

2.5.1.1. Description

Type J thermocouples are constructed of Iron/Constantin. Iron, which is the positive element, is very inexpensive, but subject to poor conformance. The J type thermocouple is however popular due to its low price, and relatively high voltage levels. J type thermocouples should never be used above 760°C, as a magnetic transformation can result in permanent decalibration. J type thermocouples also oxidize very easily.

2.5.1.2. Useful temperature range

0 to 750°C

2.5.1.3. Error limits

2.2°C or 0.75%

2.5.1.4. Color code

NBS	White/red, sheath brown
BS	Yellow/blue, sheath black
DIN	Red/blue, sheath blue
JIS	Red/white, sheath yellow
NF	Yellow/black, sheath black

2.5.2. Type K

2.5.2.1. Description

Type K thermocouples are constructed of Chromel/Alumel. Type K thermocouples are low cost, but are inclined to oxidize at high temperature, and have magnetic transformations above 500°C. Note however that K type thermocouples are less prone to oxidization than J type thermocouples.

2.5.2.2. Useful temperature range

-200 to 1250°C

2.5.2.3. Error limits

2.2°C or 0.75% above 0°C, 2.2°C or 2.00% below 0°C

2.5.2.4. Color code

NBS	Yellow/red, sheath brown
BS	Brown/blue, sheath red
DIN	Red/green, sheath green
JIS	Red/white, sheath blue
NF	Yellow/purple, sheath purple

2.5.3. Type N

2.5.3.1. Description

Type N thermocouples, constructed of Nicrosil/Nisil, are very similar to type K thermocouples, but are formulated to minimize the problems inherent with the K type thermocouple. In addition to being resistant to oxidation and being free from magnetic transitions, N type thermocouples are also immune to neutron radiation. Unlike the other base metal thermocouples, type N thermocouples have a specified composition.

2.5.3.2. Useful temperature range

-270 to 1300°C

2.5.3.3. Error limits

2.2°C or 0.75% above 0°C, 2.2°C or 2.00% below 0°C

2.5.3.4. Color code

NBS	Orange/red, sheath brown
BS	Orange/blue, sheath orange

2.5.4. Type E

2.5.4.1. Description

Type E thermocouples (Cromel/Constanin) have the highest voltage output of any commonly used thermocouple. They are thus often used for low temperature measurements, and detection of small temperature changes.

2.5.4.2. Useful temperature range

-200 to 900°C

2.5.4.3. Error limits

1.7°C or 0.5% above 0°C, 1.7°C or 1.00% below 0°C

2.5.4.4. Color code

NBS	Purple/red, sheath brown
BS	Brown/blue, sheath brown

DIN	Red/black, sheath black
JIS	Red/white, sheath purple
NF	Yellow/purple, sheath purple

2.5.5. Type T

2.5.5.1. Description

Type T thermocouples (Copper/Constantin) are the only common thermocouples to have published standard wire errors for operation below 0°C. In practice however, type E thermocouples are a better choice at low temperature, because of their higher output levels.

2.5.5.2. Useful temperature range

-200 to 350°C

2.5.5.3. Error limits

1.0°C or 0.75% above 0°C, 1.0°C or 1.5% below 0°C

2.5.5.4. Color code

NBS	Blue/red, sheath brown
BS	White/blue, sheath blue
DIN	Red/brown, sheath brown
JIS	Red/white, sheath brown
NF	Yellow/blue, sheath blue

2.6. Noble metal thermocouples

Noble metal thermocouples share many of the same characteristics. They are all platinum or platinum/rhodium types, and are far more stable than the base metal thermocouples. Noble metal thermocouples are generally used at very high temperature. At these high temperatures, metallic vapor diffusion can change the platinum wire calibration. As a result, these thermocouples are only used inside a non-metallic sheath at high temperature.

2.6.1. Type R

2.6.1.1. Description

Type R thermocouples (Platinum-13% Rhodium/Platinum) are one of the three standard high temperature noble metal thermocouples. R type thermocouples are very similar to S type thermocouples, but have a slightly higher output voltage at most temperatures.

2.6.1.2. Useful temperature range

0 to 1450°C

2.6.1.3. Error limits

1.5°C or 0.25%

2.6.1.4. Color code

NBS	Black/red, sheath brown
BS	White/blue, sheath green
JIS	Red/white, sheath black

2.6.2. Type S

2.6.2.1. Description

Type S thermocouples (Platinum-10% Rhodium/Platinum) are one of the three standard high temperature noble metal thermocouples. S type thermocouples are very similar to R type thermocouples, but have a slightly lower output voltage at most temperatures.

2.6.2.2. Useful temperature range

0 to 1450°C

2.6.2.3. Error limits

1.5°C or 0.25%

2.6.2.4. Color code

NBS	Black/red, sheath brown
BS	White/blue, sheath green
DIN	Red/white, sheath white
JIS	Red/white, sheath black
NF	Yellow/green, sheath green

2.6.3. Type B

2.6.3.1. Description

Type B thermocouples (Platinum-30% Rhodium/Platinum-6% Rhodium) are one of the three standard high temperature noble metal thermocouples. B type thermocouples have a higher temperature range than the other standard thermocouples. Although usable down to 0°C, B type thermocouples are double valued at less than 40°C and highly non-linear to about 130°C. They are thus not generally used at less than about 130°C. B type thermocouples are popular in the glass industry.

2.6.3.2. Useful temperature range

0 to 1700°C

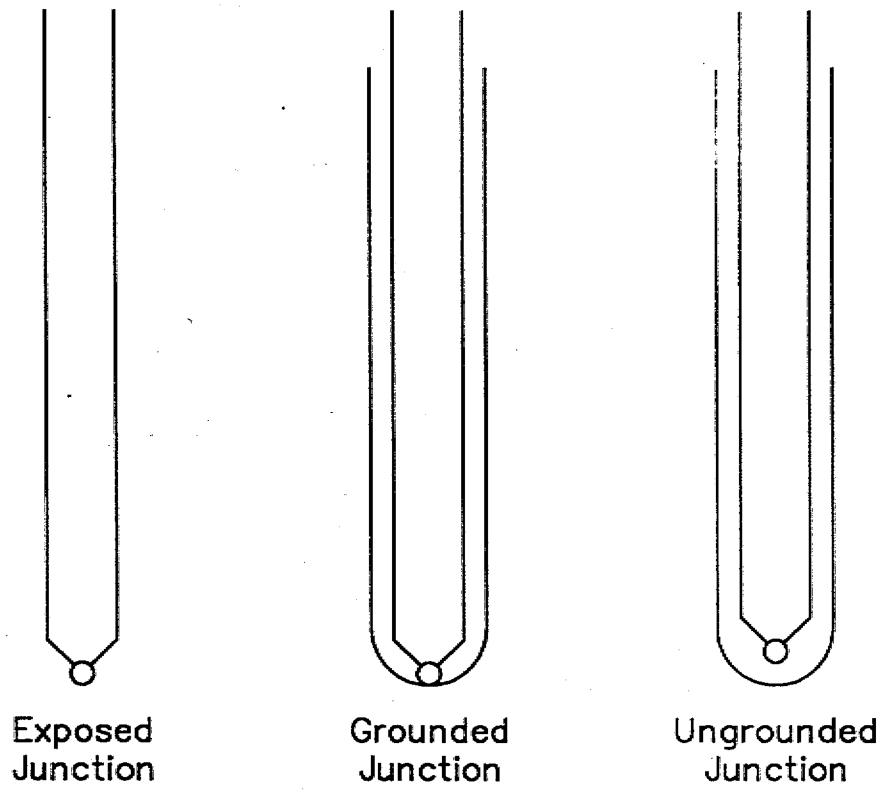

Figure 2.3. Thermocouple styles.

2.6.3.3. Error limits

1.5°C or 0.25%

2.6.3.4. Color code

NBS	Grey/red, sheath brown
DIN	Red/grey, sheath grey
JIS	Red/white, sheath grey

2.7. Other thermocouples

Various other thermocouples are available, mostly in the form of exotic high temperature tungsten types (Types G, C and D for example). These allow measurement up to 2320°C+.

These thermocouples are not official standards, and if you are using such thermocouples, you should obtain full data from your supplier.

2.8. Thermocouple styles

In addition to thermocouple type, thermocouple style is an important factor in thermocouple performance. Three basic styles are available, as illustrated in figure 2.3.

2.8.1. Exposed Junction

The exposed, or bead, junction thermocouple has its junction exposed to air. Thermocouples with exposed junctions are generally used to measure gas temperature, and have extremely fast response time.

2.8.2. Ungrounded junction

In ungrounded junction thermocouples, the thermocouple junction is protected by a conductive sheath, which is electrically isolated from the thermocouple itself. This construction is particularly useful where high levels of electrical noise are present.

The ungrounded junction thermocouple has the disadvantage that response time is long, typically of the order of several seconds. Problems can also arise from thermal shunting, resulting in the junction being at a different temperature to the sheath.

2.8.3. Grounded junction

In grounded junction thermocouples, the thermocouple junction is protected by a conductive sheath, which is electrically connected to the thermocouple junction. This has the advantage that response time is faster than the ungrounded junction type, and thermal shunting effects are minimized, while maintaining good noise immunity. Problems can however come about due to ground loops. Unfortunately, ground loop problems are particularly difficult to solve with thermocouples due to the low signal levels.

Warning
Grounded junction thermocouples should not be used with the PC-73

2.9. Thermocouple accessories

Very often, thermocouples are at a considerable distance from the measuring point, and require extension leads and connectors.

Conventional copper wire and connectors cannot be used for these extensions, as unwanted thermocouples would be created. Wire and connectors of the same material as the thermocouple must be used.

2.9.1. Extension wire

Extension wire can be used to connect from the thermocouple to the cold junction terminals, rather than actual thermocouple wire. Extension wire is considerably lower in cost than full thermocouple wire, but has a limited temperature range, typically 0 to 100°C. Extension wire must not be used to form the thermocouple junction, as it is less pure than true thermocouple wire. Note that no part of the extension must exceed the extension wire's temperature rating.

2.9.2. Connectors

If in-line connectors are used, these must also be of the same material as the thermocouple wires. Most thermocouple connectors are color coded and polarized to prevent alloy reversal.

Connector color coding is as follows:

J	Black
K	Yellow
N	Orange
E	Purple
T	Blue
R	Green
S	Green
U	White (uncompensated, copper)

Note that white connectors are simple copper, and are used for thermistors, RTD etc, as well as B type thermocouples. B type thermocouples can use copper extensions as output at low temperature is negligible. Grey connectors are also sometimes used for B type thermocouples.

2.10. Using thermocouples

Thermocouples are generally robust, easy-to-use devices. However, a certain amount of care is required to avoid erroneous results:

2.10.1. Poor junction connection

Poor junction connection is a prime cause of thermocouple problems. Errors of the order of 10s of degrees can occur with thermocouple wires simply twisted together. Acceptable ways of forming the junction are soldering, silver soldering and welding.

- Don't attempt to make up a thermocouple yourself. Among other problems, the junction can become contaminated, and excessive heat can cause decalibration. Commercial thermocouples are welded via an expensive capacitive-discharge method. Buying a made-up thermocouple is not expensive, and can save you a lot of trouble.

- Don't EVER use twisted wires to form a thermocouple. This is virtually guaranteed to result in substantial errors in measurement. Many thermocouple metals form a thin layer of oxide immediately on exposure to air. This is not harmful, except if it forms the measuring junction!

- Never mix thermocouple wires, or replace only one lead of a thermocouple. The two leads of a particular batch of wire are often matched. Wire with the same name in different thermocouples is often not the same. For example, the Constantin in a type J thermocouple is NOT the same as the Constantin in a type T thermocouple.

2.10.2. Decalibration

Decalibration can be a very serious fault condition, because it results in measurements which appear to be correct, but can have substantial errors.

Decalibration results from unintentionally altering the physical makeup of the thermocouple, so that it no longer conforms to its characteristic curve. Decalibration can result from:

- Diffusion of atmospheric particles into the thermocouple as a result of temperature extremes.

- Cold-working the metal, for example by drawing the wire through a conduit, or by vibration.

- Annealing, due to a temperature gradient in a section of the wire.

It's important to realize that although a thermocouple effectively measures the temperature of the junction, the actual voltage is generated in the section of the wire that contains the temperature gradient. Hence, the entire length of thermocouple wire, not just the junction, forms the sensor, and must be treated with care.

2.10.3. Galvanic action

Atmospheric particles, as well as the dyes used in some thermocouple insulations, can form an electrolyte in the presence of water. This can create a galvanic junction, with a resultant output hundreds of times greater than the thermocouple voltage, leading to gross errors.

2.10.4. Noise

Electrical noise can result in substantial measurement errors. The PC-73 makes use of an integrating converter to reduce this as much as possible.

In cases of severe noise, shielded cables should be used, with the shield tied to the thermocouple sheath.

2.10.5. Thermal shunting

Thermocouples also have thermal characteristics of their own. You should watch out for two thermal shunting effects:

- Any thermocouple has mass. As a result, it requires energy to heat, and will thus slightly alter the temperature it is intended to measure.

- The legs of the thermocouple, being metal, are good heat conductors. They thus act as heat pipes, causing the junction to at a different temperature to the substance to be measured. Ungrounded thermocouples, due to their construction, are particularly prone to this problem.

As a general rule, a thermocouple assembly should be inserted to a depth of at least 10 times its outside diameter into whatever it is measuring the temperature of.

Wherever possible, when installing thermocouples with a sheath, you should compare the reading obtained with readings obtained with an exposed junction thermocouple.

2.10.6. Conditions of operation

Thermocouple assemblies are generally designed with a specific use in mind, and should not be used under substantially different conditions. If your application involves operation at extreme temperatures, or in reducing or oxidizing atmospheres, you should obtain advice from your thermocouple supplier.

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Chapter 3

Architecture

This chapter describes the architecture of the PC-73 board. The block diagram in figure 3.1 highlights the major elements contained on the board, and their interrelationship. There are five major subsections. These are the following:

3.1. External terminal block board

The external terminal block board is an integral part of the PC-73. The temperature of the terminal block is sensed, and transmitted to the PC-73 main board, so allowing cold junction compensation. The temperature sensor has a scale factor of 10 mV per °C.

3.2. The Relay Multiplexer

The multiplexer selects one of eight differential thermocouple input channels, or the cold-junction compensation channel. The channel is selected by a channel address, obtained from the channel register.

3.3. Instrumentation Amplifier

The instrumentation amplifier is a precision differential amplifier, designed for high stability and minimum drift. It amplifies the thermocouple voltage from the relay multiplexer by a fixed value. This can be jumper selected to 1, 100, 200 or 500. A value of 100 matches most thermocouples, and is the default setting. Note that the cold-junction compensation voltage is NOT amplified by the instrumentation amplifier, but is fed directly to the A/D converter.

3.4. A/D Subsystem

The A/D converter performs the actual A/D conversion. A/D conversions are started via the

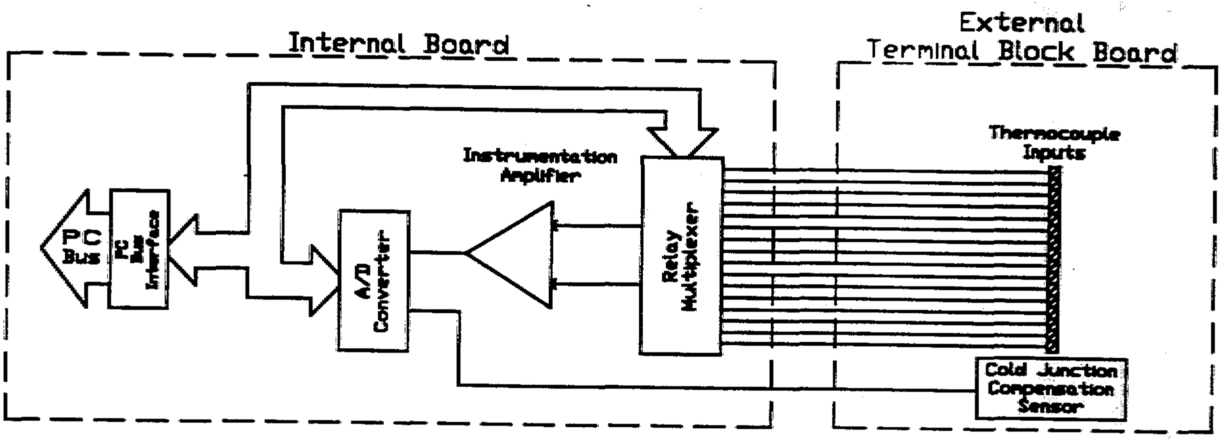

Figure 3.1. PC-73 block diagram.

control register. The A/D converter has an input range of -4.096 to +4.096 Volts.

3.5. Bus interface

The bus interface is responsible for the decoding of the board's base address. The board's base address is set by a DIP switch.

Chapter 4

Configuring the board

4.1. Introduction

The PC-73 boards can be configured to suit each user's individual requirements. This configuration is set by the position of the various mini-jumps on the board, and the setting of the DIP switch. Each set of mini-jumps controls a specific aspect of the operation of the board. These are as follows:

i. Bus interface. The base address of the board can be set. As supplied by the factory, the base address is set to 380H. This allows operation in a standard PC/XT/AT which contains only conventional boards (Multifunction boards, disk controller boards, display boards etc), but may require modification if exotic boards (other scientific boards, certain backup systems etc) are installed.

ii. Instrumentation amplifier gain. The gain may be set to 1, 100, 200 or 500.

4.2. Changing the Configuration

In order to change the DIP switch or jumper settings, follow the procedure below:

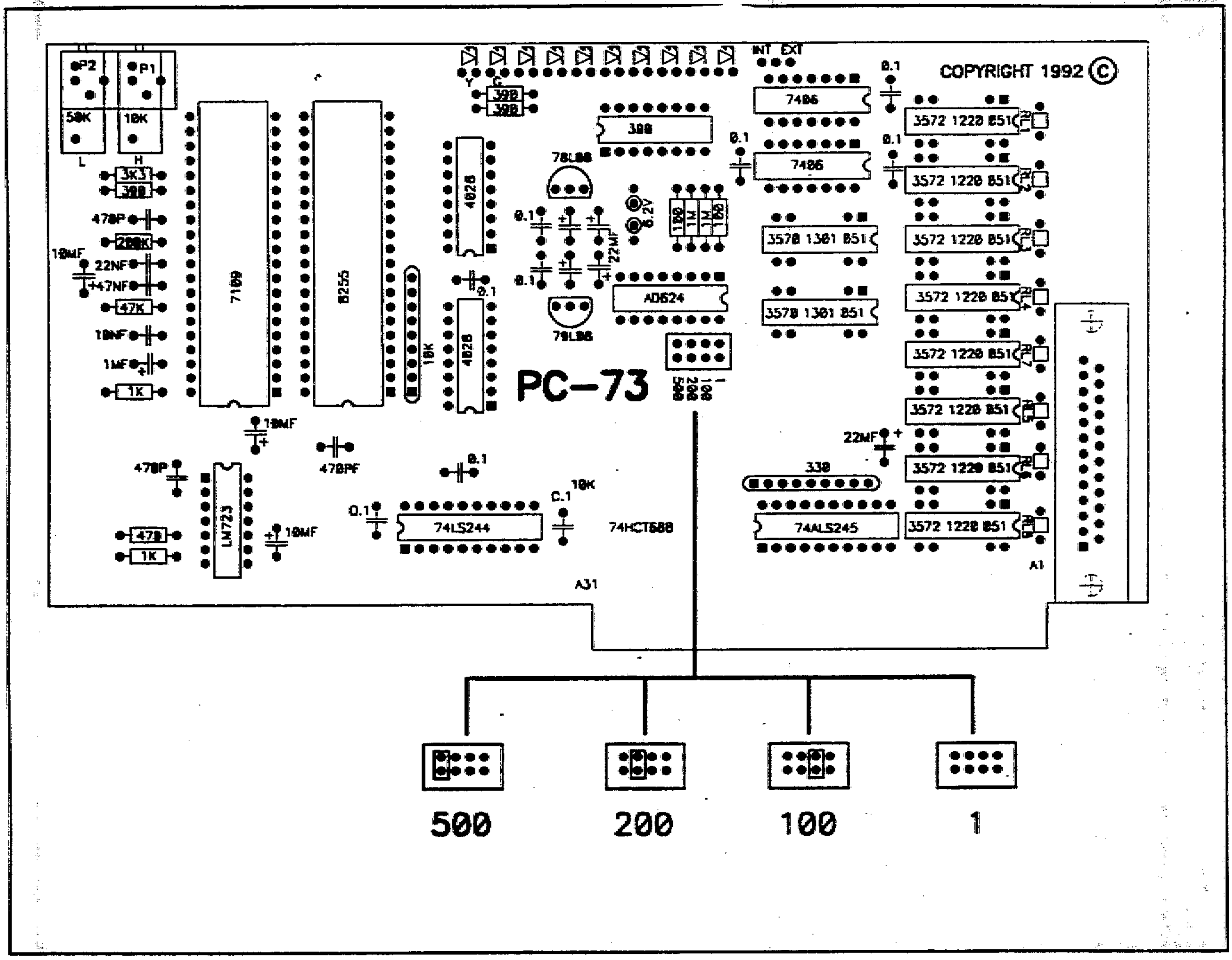

Figure 4.1. PC-73 gain jumper settings

i. Switch off the computer.

ii. Remove the board.

iii. Change the required jumper or DIP switch settings.

iv. Replace the board in the PC.

v. Power up, and run a program (such as PC73.EXE), which executes the PC-73 diagnostics routines.

4.3. Instrumentation amplifier gain setting

The instrumentation amplifier's gain may be set via the jumpers shown in figure 4.1, so effectively setting the A/D input range.

4.4. Bus Interface Configuration

4.4.1. Base address

The base address setting is controlled via the board DIP switch. As supplied by the factory, the address is set to 380H. The board occupies 4 consecutive locations. Table 4.1 shows the DIP switch settings for the PC-73.

Base Addr.	SW8	SW7	SW6	SW5	SW4	SW3	SW2	SW1
200H	on	on	on	on	on	on	on	off
204H	off	on	on	on	on	on	on	off
208H	on	off	on	on	on	on	on	off
20CH	off	off	on	on	on	on	on	off
210H	on	on	off	on	on	on	on	off
214H	off	on	off	on	on	on	on	off
218H	on	off	off	on	on	on	on	off
21CH	off	off	off	on	on	on	on	off
220H	on	on	on	off	on	on	on	off
224H	off	on	on	off	on	on	on	off
228H	on	off	on	off	on	on	on	off
22CH	off	off	on	off	on	on	on	off
230H	on	on	off	off	on	on	on	off
234H	off	on	off	off	on	on	on	off
238H	on	off	off	off	on	on	on	off
23CH	off	off	off	off	on	on	on	off
240H	on	on	on	on	off	on	on	off
244H	off	on	on	on	off	on	on	off
248H	on	off	on	on	off	on	on	off
24CH	off	off	on	on	off	on	on	off
250H	on	on	off	on	off	on	on	off
254H	off	on	off	on	off	on	on	off
258H	on	off	off	on	off	on	on	off
25CH	off	off	off	on	off	on	on	off
260H	on	on	on	off	off	on	on	off
264H	off	on	on	off	off	on	on	off
268H	on	off	on	off	off	on	on	off
26CH	off	off	on	off	off	on	on	off
270H	on	on	off	off	off	on	on	off
274H	off	on	off	off	off	on	on	off
278H	on	off	off	off	off	on	on	off
27CH	off	off	off	off	off	on	on	off
280H	on	on	on	on	on	off	on	off

Table 4.1. PC-73 base address settings.

Base Addr.	SW8	SW7	SW6	SW5	SW4	SW3	SW2	SW1
284H	off	on	on	on	on	off	on	off
288H	on	off	on	on	on	off	on	off
28CH	off	off	on	on	on	off	on	off
290H	on	on	off	on	on	off	on	off
294H	off	on	off	on	on	off	on	off
298H	on	off	off	on	on	off	on	off
29CH	off	off	off	on	on	off	on	off
2A0H	on	on	on	off	on	off	on	off
2A4H	off	on	on	off	on	off	on	off
2A8H	on	off	on	off	on	off	on	off
2ACH	off	off	on	off	on	off	on	off
2B0H	on	on	off	off	on	off	on	off
2B4H	off	on	off	off	on	off	on	off
2B8H	on	off	off	off	on	off	on	off
2BCH	off	off	off	off	on	off	on	off
2C0H	on	on	on	on	off	off	on	off
2C4H	off	on	on	on	off	off	on	off
2C8H	on	off	on	on	off	off	on	off
2CCH	off	off	on	on	off	off	on	off
2D0H	on	on	off	on	off	off	on	off
2D4H	off	on	off	on	off	off	on	off
2D8H	on	off	off	on	off	off	on	off
2DCH	off	off	off	on	off	off	on	off
2E0H	on	on	on	off	off	off	on	off
2E4H	off	on	on	off	off	off	on	off
2E8H	on	off	on	off	off	off	on	off
2ECH	off	off	on	off	off	off	on	off
2F0H	on	on	off	off	off	off	on	off
2F4H	off	on	off	off	off	off	on	off
2F8H	on	off	off	off	off	off	on	off
2FCH	off	off	off	off	off	off	on	off
300H	on	on	on	on	on	on	off	off
304H	off	on	on	on	on	on	off	off
308H	on	off	on	on	on	on	off	off
30CH	off	off	on	on	on	on	off	off
310H	on	on	off	on	on	on	off	off
314H	off	on	off	on	on	on	off	off
318H	on	off	off	on	on	on	off	off
31CH	off	off	off	on	on	on	off	off
320H	on	on	on	off	on	on	off	off
324H	off	on	on	off	on	on	off	off
328H	on	off	on	off	on	on	off	off
32CH	off	off	on	off	on	on	off	off
330H	on	on	off	off	on	on	off	off
334H	off	on	off	off	on	on	off	off
338H	on	off	off	off	on	on	off	off
33CH	off	off	off	off	on	on	off	off

Table 4.2. PC-73 base address settings (cont).

Base Addr.	SW8	SW7	SW6	SW5	SW4	SW3	SW2	SW1
340H	on	on	on	on	off	on	off	off
344H	off	on	on	on	off	on	off	off
348H	on	off	on	on	off	on	off	off
34CH	off	off	on	on	off	on	off	off
350H	on	on	off	on	off	on	off	off
354H	off	on	off	on	off	on	off	off
358H	on	off	off	on	off	on	off	off
35CH	off	off	off	on	off	on	off	off
360H	on	on	on	off	off	on	off	off
364H	off	on	on	off	off	on	off	off
368H	on	off	on	off	off	on	off	off
36CH	off	off	on	off	off	on	off	off
370H	on	on	off	off	off	on	off	off
374H	off	on	off	off	off	on	off	off
378H	on	off	off	off	off	on	off	off
37CH	off	off	off	off	off	on	off	off
380H	on	on	on	on	on	off	off	off
384H	off	on	on	on	on	off	off	off
388H	on	off	on	on	on	off	off	off
38CH	off	off	on	on	on	off	off	off
390H	on	on	off	on	on	off	off	off
394H	off	on	off	on	on	off	off	off
398H	on	off	off	on	on	off	off	off
39CH	off	off	off	on	on	off	off	off
3A0H	on	on	on	off	on	off	off	off
3A4H	off	on	on	off	on	off	off	off
3A8H	on	off	on	off	on	off	off	off
3ACH	off	off	on	off	on	off	off	off
3B0H	on	on	off	off	on	off	off	off
3B4H	off	on	off	off	on	off	off	off
3B8H	on	off	off	off	on	off	off	off
3BCH	off	off	off	off	on	off	off	off
3C0H	on	on	on	on	off	off	off	off
3C4H	off	on	on	on	off	off	off	off
3C8H	on	off	on	on	off	off	off	off
3CCH	off	off	on	on	off	off	off	off
3D0H	on	on	off	on	off	off	off	off
3D4H	off	on	off	on	off	off	off	off
3D8H	on	off	off	on	off	off	off	off
3DCH	off	off	off	on	off	off	off	off
3E0H	on	on	on	off	off	off	off	off
3E4H	off	on	on	off	off	off	off	off
3E8H	on	off	on	off	off	off	off	off
3ECH	off	off	on	off	off	off	off	off
3F0H	on	on	off	off	off	off	off	off
3F4H	off	on	off	off	off	off	off	off
3F8H	on	off	off	off	off	off	off	off
3FCH	off	off	off	off	off	off	off	off

Table 4.3. PC-73 base address settings (cont).

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Chapter 5

Interconnections

5.1. Introduction

The PC-73 plugs into IBM PC/XT/AT or compatible expansion slots at connector P1. Connection to the user's circuitry is made at the terminal block on the external board. This chapter describes these two connectors.

5.2. Connections to the IBM backplane

PC-73 boards can be plugged into any slot of the IBM backplane, with the exception of the J8 slot of the XT. This particular slot requires the -CARDSLCT signal, which is not used on other slots. All communication to and from the host processor is carried out via this connector.

5.3. User connection

The PC-73 is connected to the user's thermocouples via the external terminal block board. Connections to this are shown in figure 5.1. Channel numbers are also marked on the board itself.

5.4. Connection guidelines

The PC-73 is intended for connection to either exposed or ungrounded type thermocouples, as discussed in chapter 2. All that is required is to connect the two thermocouple leads to the PC-73 terminal block.

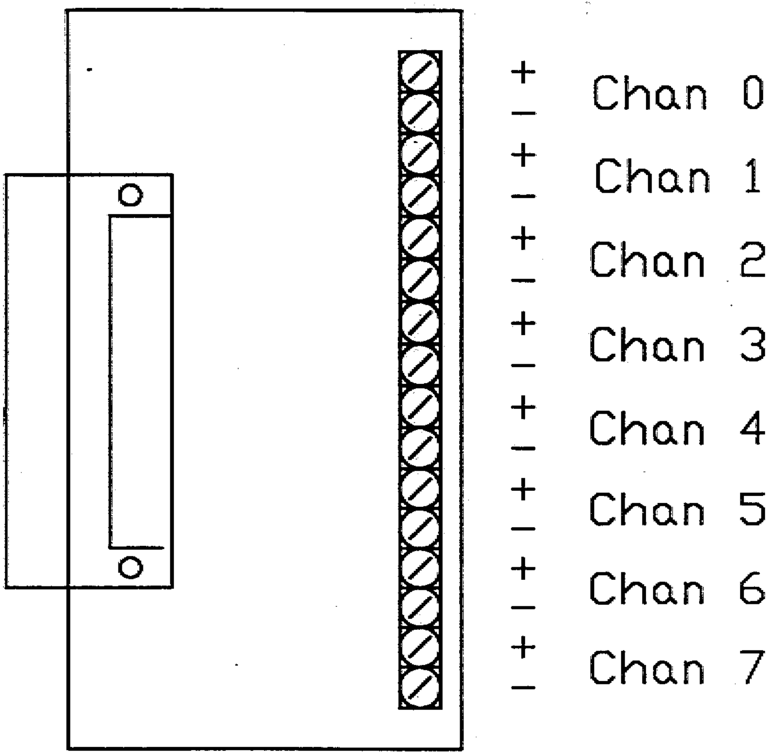

Figure 5.1. PC-73 screw terminal board connections.

Warning
Note that both leads of any thermocouple connected to the PC-73 must be completely isolated. The PC-73 itself does NOT have isolated inputs. Do not ground either thermocouple's lead, or use grounded junction thermocouples.

The PC-73 can be factory modified to operate with grounded junction type thermocouples. Consult your dealer for more details.

Chapter 6

Register structure

6.1. Introduction

At the lowest level, the PC-73 can be programmed using I/O input and output instructions. This chapter contains the information required to do this. Although not difficult, this is time consuming, and requires detailed knowledge of the PC-73, as well as the operation of the host PC and its operating system. In order to simplify this process, a set of device drivers is available for use with the board. The use of these allows access to all board functions. These drivers are described in the next chapter of this manual.

The next chapter discusses various programming techniques and tips.

6.2. Register structure

The PC-73 uses 4 consecutive address locations in I/O space. The layout of these registers is shown in figure 6.1.

Note that the addresses above are given as offsets from the base address of the board. This base address is DIP switch selected as described in chapter 3.

Each register will now be described in detail.

Warning
You should not write to, or read from, unused registers. All unused registers are reserved for manufacturing test, or for future developments.

Offset From Base	Register Name	
	Read	Write
0	Channel Register (ADCHR)	
1	A/D Data/Status(ADDSR)	——
2	A/D Control (ADCNTRL)	
3	——	Mode Register (ADMDE)

Figure 6.1. PC-73 Register Structure.

6.2.1. ADCHR - A/D Control/channel register (offset 0)

The ADCHR contains channel address bits. The bit functions of the ADCHR are shown in figure 6.2.

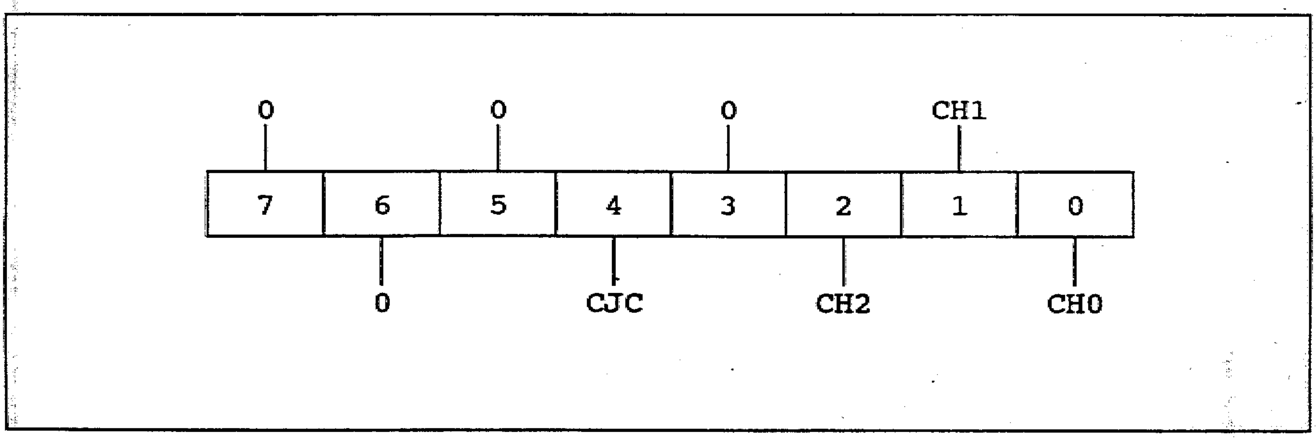

Figure 6.2 Channel register.

Bits 7-5 - Reserved (0)

These bits are reserved, and should be written with 0. The results of reading these bits are undefined.

Bit 4 - CJC

If bit 4 is set, then the cold-junction compensation temperature is read. If it is zero, then the thermocouple input channel indicated by the channel bits is read.

Bit 3 - Reserved (0)

This bit is reserved, and should be written with 0. The results of reading this bit are undefined.

Bits 2-0 - CH

These bits specify a three bit channel address. This channel is the channel which will be converted on the next A/D strobe, if the CJC bit is clear.

Warning
After changing the value in the ADCHR register, at least 1 millisecond must elapse prior to starting a new A/D conversion cycle.

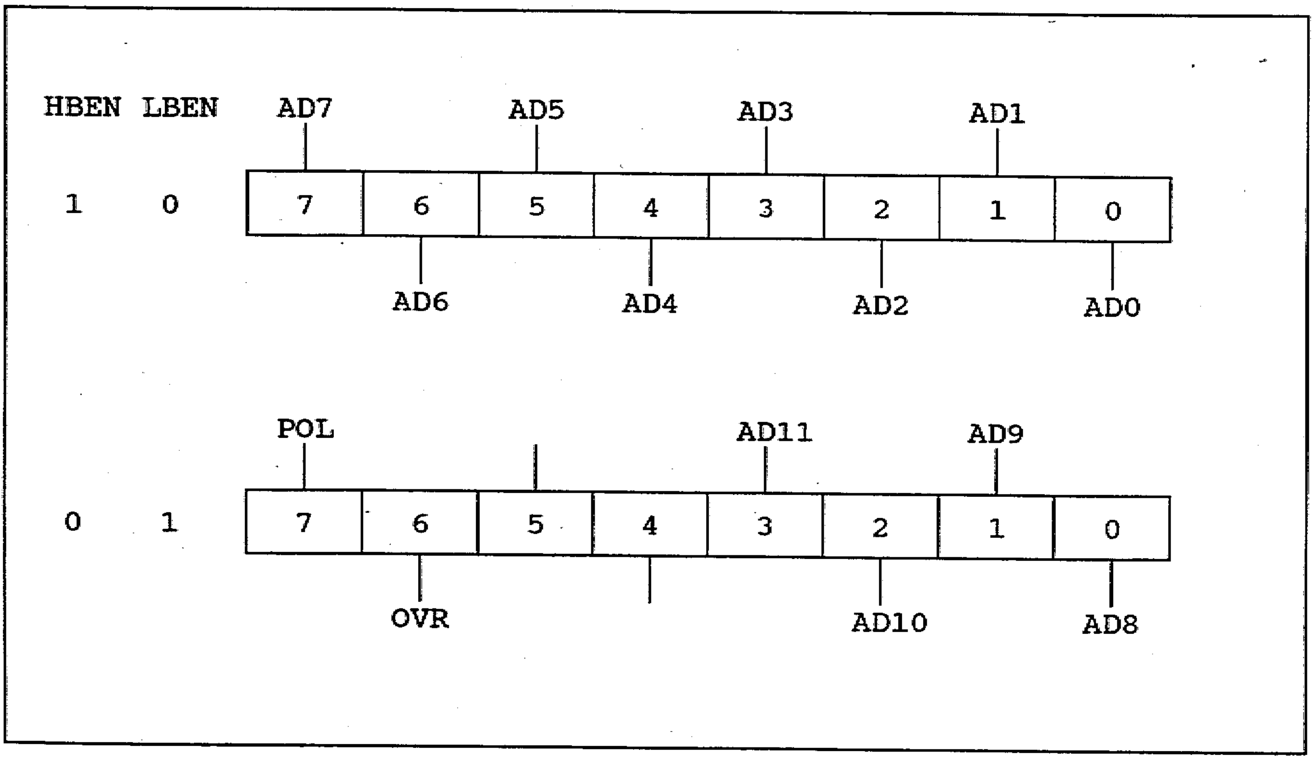

Figure 6.3. A/D data/status register.

6.2.2. ADDSR - A/D data/ status register (offset 1) (read only)

The ADDSR register contains either:

- the least significant byte of the A/D result, or
- the upper 4 bits of the A/D result, and the A/D status.

The register function is selected by the HBEN and LBEN bits in the Control register.

Bit 0 is the LSB. The layout of this register is shown in figure 6.3.

Bits 7-0 - A/D data (AD)

These bits are the 12-bit code which is returned from an A/D conversion.

Bit 7 - POL

This is the polarity bit. If it is set, then the measured voltage is positive.

Bit 6 - OVR

This is the overrange bit. If it is set, then the measured voltage is out of the converter's range.

6.2.3. ADCNTRL - A/D Control/Status (offset 2) (read/write)

The ADCNTRL register contains control bits for the A/D, as well as status bits. The bit functions of the ADMDE register are shown in figure 6.4.

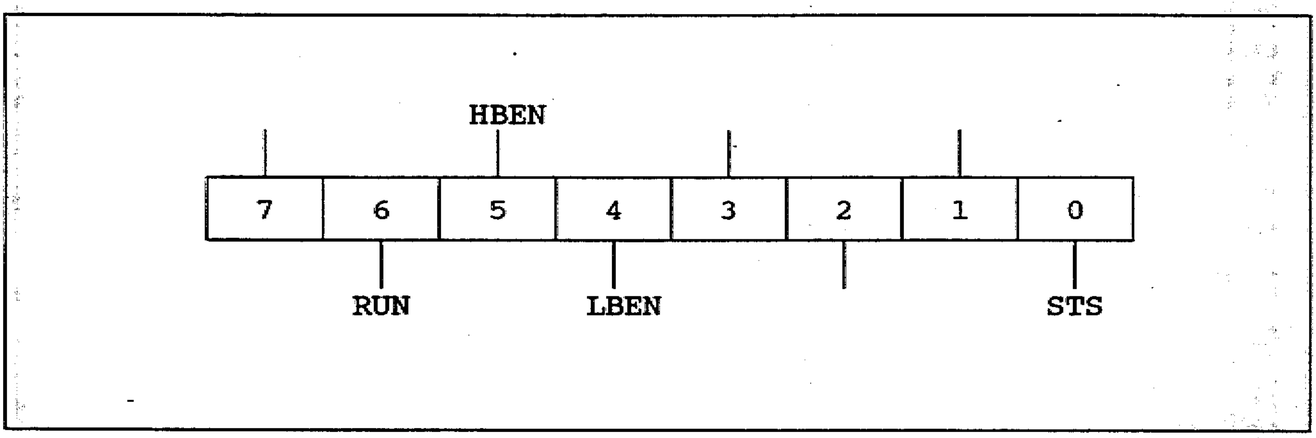

Figure 6.4. A/D moae register.

Bit 6 - RUN (read/write)

In order to start a conversion, a logical one is written to this bit. Bits 4 and 5 should be 1, and all other bits zero. Once the STS bit has gone high, and then returned to 0, the RUN bit may be cleared.

Bit 5 - HBEN (read/write)

If the HBEN bit is low, then the high 4 bits of the A/D result, and the A/D status bits, appear in the ADDSR.

Bit 4 - LBEN (read/write)

If the LBEN bit is low, then the lower 8 bits of the A/D result appear in the ADDSR.

Note that HBEN and LBEN must never be 0 simultaneously. It is advisable to set both bits high prior to setting either bit low.

Bit 0 - STS (read only)

Once an A/D conversion begins, the STS bit goes high. When the A/D conversion ends, and data from the conversion is ready, the STS bit returns low.

6.2.4. ADMDE - A/D mode register (offset 3)

The ADMDE register contains A/D mode selection bits. The bit functions of the ADMDE register are shown in figure 6.5.

Note
The value 83 (hex) must be written to the ADMDE register prior to any other activity.

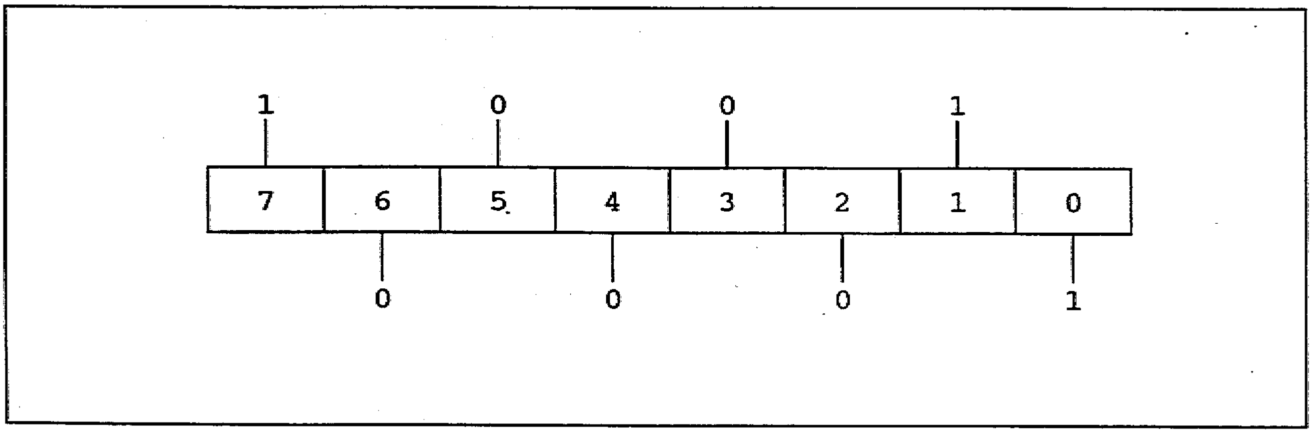

Figure 6.5. A/D mode register.

Bit 7 - Reserved (1)

For compatibility with future products, you must write a 1 to this bit. The results of reading this bit are undefined.

Bit 6 - Reserved (0)

For compatibility with future products, you must write a 0 to this bit. The results of reading this bit are undefined.

Bit 5 - Reserved (0)

For compatibility with future products, you must write a 0 to this bit. The results of reading this bit are undefined.

Bit 4 - Reserved (0)

For compatibility with future products, you must write a logical 0 to this bit. The results of reading this bit are undefined.

Bit 3 - Reserved (0)

For compatibility with future products, you must write a 0 to this bit. The results of reading this bit are undefined.

Bit 2 - Reserved (0)

For compatibility with future products, you must write a 0 to this bit. The results of reading this bit are undefined.

Bit 1 - Reserved (1)

For compatibility with future products, you must write a 1 to this bit. The results of reading this bit are undefined.

Bit 0 - Reserved (1)

For compatibility with future products, you must write a 1 to this bit. The results of reading this bit are undefined.

6.3. Programming Guide

This section gives a "how-to" guide to programing the PC-73. Driver software for the PC-73 is described in the next chapter, and where possible you should make use of this software, rather than write your own. However, if you do decide to write your own low-level code, we strongly recommend that you study the source code for the drivers. This code is found on the diskette supplied with the driver software package.

6.3.1. Initialization

In order to initialize the PC-73, the following steps should be performed. The function Init, supplied with the PC-73 driver software, performs this function. This sequence should be followed prior to attempting any function.

i. Write 83(hex) to the A/D mode register (ADMDE).

ii. Write 30(hex) to the A/D control register (ADCNTRL).

iii. A simple test for the presence of the PC-73 can be performed by reading back the upper 4 bits of the ADCNTRL register, and comparing them to the value written.

The PC-73 is then ready for operation.

6.3.2. Obtaining a single A/D reading

To obtain a single A/D reading under program control, proceed as follows:

i. Write the address of the channel you wish to convert, to the ADCCR.

ii. Wait for at least 1 mS, to allow the relay multiplexer to settle.

iii. Write 70 (hex) to the ADCNTRL register.

iv. Wait for the STS bit in the ADCNTRL register to go high, then low.

v. Write 30 (hex) to the ADCNTRL register.

vi. Write 20 (hex) to the ADCNTRL register.

vii. Read in the low byte of the A/D result from the ADDSR register.

viii. Write 10 (hex) to the ADCNTRL register.

ix. Read in the four high bits of the A/D result, and the polarity and overrange bits from the ADDSR register.

x. Write 30 (hex) to the ADCNTRL register.

xi. If the polarity bit was high, then the result is positive, else negative.

6.3.3. Overlapping Relay setting time

If a sequence of A/D samples is to be obtained, then the relay setting time and the A/D converter auto-zero period can be overlapped, improving the PC-73's throughput. In order to do this, the next channel address must be written to the channel register as soon as STS returns low on the current sample. If this is done, then the 1 mS second time delay can be omitted.

In the supplied driver software, the Ad_in routine assumes that the next channel to be converted will be the subsequent channel. This improves performance in most scanner applications.

6.3.4. Converting from binary to analog values

Analog data from the A/D converter is always in the form of binary code with a sign bit. Analog voltages may be calculated from the digital codes most simply by noting that one LSB has a specific weight for each instrumentation amplifier gain. It is thus necessary only to multiply the integer result from the A/D by this weight.

6.3.4.1. Thermocouple inputs

For thermocouple inputs, the bit weights are as follows:

Gain	Bit weight
100 (default)	10 uV

1	1 mV
200	5 uV
500	2 uV

6.3.4.2. Cold-junction compensation input

For the cold-junction compensation input, the bit weight is as follows:

Bit weight
1 mV

This results in an effective bit weight of 0.1 degrees C per bit.

Chapter 6

Software

This chapter describes the software supplied with the PC-73. This consists of two distinct products; the PC-73 driver software, and the PC-73 demonstration/calibration program.

7.1. Driver software

This consists of a set of real time device drivers for use with the PC-73 board. These device drivers are supplied in C and BASIC, and are callable from most compiled languages, including the following:

- Microsoft C version 5.1.
- Turbo C version 1.5.
- Microsoft QuickBasic version 4.5.

The driver software allows programers to control the PC-73 via high level function calls, so allowing users to write custom software without understanding the low level operation of the PC-73. Thermocouple linearisation for type J, K, E, T, B, R, S and N thermocouples is supported. Also included with the driver package is complete source code, in C and Basic, for the entire driver package. This allows advanced users to modify existing code, rather than having to start writing low level code from scratch.

7.1.1. Driver format

The driver package comes in the form of a single module. This module consists of a single program file, and a single include file. Identical versions are supplied in C, and in Basic. Microsoft C, Turbo C, and Microsoft QuickBasic are specifically supported, but most other compilers should also be able to compile these modules.

The file names in question are:

C	DACQPC.C, and DACQPC.H
Basic	DACQPC.BAS, and DACQPC.INC

These two modules are also fully compatible with the LabWindows integrated environment.

All driver operations are performed by calling functions, which return a status code. The possible status codes are described in the next section.

The driver system is designed to allow support of multiple boards.

7.1.1.1. Differences between C and QuickBasic versions

The driver is supplied with source code for both C and QuickBasic. These versions are identical, with the exception of the naming of procedures and constants. Where C names use an underscore ("_"), QuickBasic names make use of a period (".").

For example, the initialization function is called Init_brd in C, and Init.brd in QuickBasic.

7.1.2. Return Codes

Two possible return codes are supported:

7.1.2.1. ERR_NOT_AVAIL (-1)

The ERR_NOT_AVAIL return code (ERR.NOT.AVAIL in Basic) indicates that the board was not available, or the requested function is not available for that type of board.

7.1.2.2. RETURN_OK (0)

The RETURN_OK return code (RETURN.OK in Basic) indicates that the function was correctly performed.

7.1.3. Microsoft C/QuickC

All supplied modules are directly compatible with Microsoft C version 5.1, as well as QuickC. You can compile the DACQPC.C module using any supported memory model. For example, using the large model:

cl /AL /c dacqpc.c

7.1.3.1. Required files

DACQPC.C, DACQPC.H

7.1.3.2. Examples

The PC73 application program is written in Microsoft C. Full source code is on the distribution disk.

7.1.4. Turbo C

All supplied modules are directly compatible with Turbo C version 1.5. You can compile the DACQPC.C module using any supported memory model.

7.1.4.1. Required files

DACQPC.C, DACQPC.H

7.1.5. Microsoft QuickBasic

Microsoft QuickBasic version 4.5 is fully supported for both the stand-alone and integrated environment operation. As in the case of the other languages, the driver is supplied in source code form.

7.1.5.1. Required files

DACQPC.INC, DACQPC.BAS

7.2. LabWindows support

Included with the supplied driver is full support for LabWindows V1.2. This support is in the form of an instrument module, and its associated information.

The LabWindows code and functions are identical to the standard libraries described above, but are supplied in the form of three files:

DACQPC.LBW, DACQPC.LWI, DACQPC.FP

These three files contain, in addition to the programs code, instrument front panels and help information for use in the LabWindows integrated environment.

In order to install the driver, all that is necessary is to copy the three files to the LabWindows instrument subdirectory. You can then use the instrument module just as you would any other.

7.3. Function reference

The DACPC driver as supplied with the PC-73 requires only four function calls. These are the following:

Init_brd	Initializes up one of up to eight boards.
Ad_in	Obtains a "raw" (integer) measurement from a board.
Volts2temp	Converts from a thermocouple voltage to temperature.
Temp_in	Obtains a temperature reading from a board.

Each of these functions will now be described in detail.

7.3.1. Ad_in

Name :	Ad_in - Gets a single A/D input reading.
Boards Supported :	PC-73
C Usage :	#include <DACQPC.H>
	int ad_in(int iBrd_num, int iChan, int *piRes);
QuickBasic Usage :	REM $INCLUDE: 'DACQPC.INC'

FUNCTION ad.in%(BYVAL iBrd.num%, BYVAL iChan%, SEG piRes%)

Description : This function obtains an integer sample from channel iChan on board iBrd, and places the result in the integer variable piRes. The result varies from -4095 to +4095. The board must first have been initialized with Init_brd.

Channel numbers from 0 to 7 refer to thermocouple channels, and channel 8 is the cold junction compensation channel. Remember that the thermocouple and cold junction channels have different scale factors.

Return value : RETURN_OK - operation performed

ERR_NOT_AVAIL - Board not present or not initialized.

Example : PC73.C

7.3.2. Init_brd

Name : Init_brd - Initializes a PC-73.

Boards Supported : PC-73

C Usage : #include <DACQPC.H>

int Init_brd(int iBrd_num, int iBrd_type, int iBase_addr);

QuickBasic Usage : REM $INCLUDE: 'DACQPC.INC'

FUNCTION Init.brd%(BYVAL iBrd.num%, BYVAL iBrd.type%, BYVAL Base.addr%)

Description : This function initializes the board at address Base_addr. In subsequent calls to the driver, it will be identified by the Brd_num parameter. The Brd_type parameter must be set to 7.

Return value : RETURN_OK - Board initialized

ERR_NOT_AVAIL - Board not found, or faulty

Example : PC73.C

7.3.3. Temp_in

Name : Temp_in - Obtains a temperature reading from a PC-73.

Boards Supported : PC-73

C Usage : #include <DACQPC.H>

int Temp_in(int iBrd_num, int iChan, int iType, double *pdTemp);

QuickBasic Usage : REM $INCLUDE: 'DACQPC.INC'

FUNCTION ad.in%(BYVAL iBrd.num%, BYVAL iChan%, BYVAL iType%, SEG pdTemp#)

Description :

This function obtains a temperature sample from channel iChan on board iBrd, and places the result in the double variable pdTemp. The board must first have been initialized with Init_brd. The iType variable defines the thermocouple type as follows :

Type J - 0

Type K - 1

Type E - 2

Type T - 3

Type S - 4

Type R - 5

Type B - 6

Type N - 7

This function is equivalent to calls to Ad_in to obtain the cold-junction temperature and the thermocouple voltage, followed by a call to Volts2temp to obtain the temperature.

For information on the accuracy of the conversion process, see appendix B.

Return value :

RETURN_OK - operation performed

ERR_NOT_AVAIL - Board not present or initialized.

Example :

PC73.C

7.3.4. Volts2temp

Name :

Volts2temp - Converts a thermocouple voltage and cold junction temperature to a thermocouple junction temperature.

Boards Supported :

PC-73

C Usage :

```
#include <DACQPC.H>

double Volts2temp(int iThermo, double dVolts, double dTemp);
```

QuickBasic Usage :

```
REM $INCLUDE: 'DACQPC.INC'

FUNCTION Volts2temp#(BYVAL iThermo%, BYVAL dVolts#,
BYVAL dTemp#)
```

Description :

This function converts from thermocouple voltage to temperature. In order to perform this function, the thermocouple voltage (dVolts), the thermocouple type (iThermo) and the cold junction temperature (dTemp) must be given. The iThermo variable defines the thermocouple type as follows:

Type J - 0

Type K - 1

Type E - 2

Type T - 3

Type S - 4

Type R - 5

Type B - 6

Type N - 7

Note that the thermocouple voltage is in volts, and the cold junction temperature and return value are in °C.

For information on the accuracy of the conversion process, see appendix B.

Return value : Thermocouple junction temperature in °C.

Example : PC73.C

7.4. Demonstration/Calibration programs

The demonstration/calibration program is an application program, which combines the features of a thermocouple scanner and calibration program in one package. J, K, E, T, B, R, S and N type thermocouples are supported.

The package is fully menu driven. Choices are made via the cursor, <enter> and numeric < + > and <-> keys.

Chapter 8

Calibration

8.1. Introduction

This chapter contains information on the calibration procedures for the A/D on the PC-73 board.

This procedure should be performed at six month intervals, or whenever the input range jumpers are changed.

NOTE
Allow the host PC and the board to warm up for at least one hour before calibration.

8.2. A/D calibration

A/D calibration is performed by adjusting two trimpots, for offset and for gain. These trimpots are easily located from the board layout in figure 8.1.

8.2.1. Requirements

i. Calibration is done on channel 0. The recommended connector wiring is shown in figure 8.2.

ii. Calibration is performed with the board jumpered into its intended operating mode.

iii. All cables should be as short as possible.

8.2.2. Equipment required

i. Precision voltage source. Range +10 to -10 V, absolute accuracy better than 0.005%, resolution 100 nV or better.

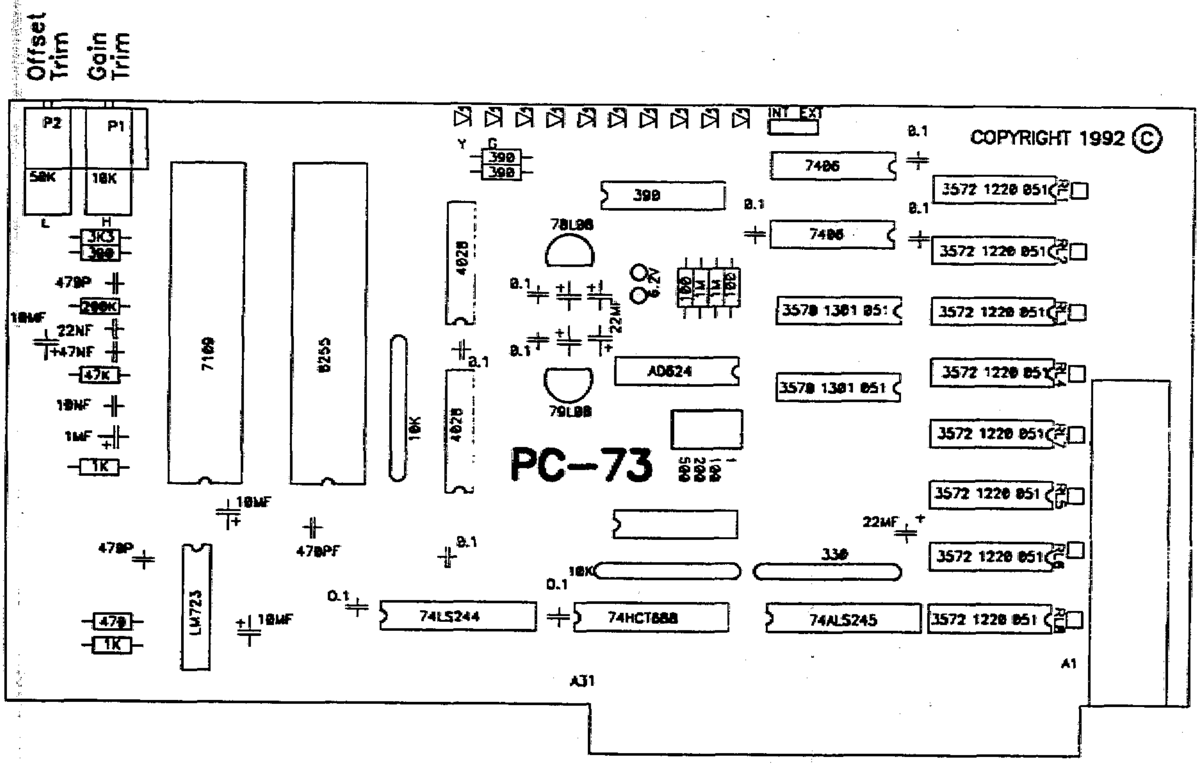

Figure 8.1. Trim locations.

8.2.3. Procedure

i. Apply 0V to channel 0. Adjust the offset trimpot for an output code which flickers evenly between +0 and -0.

ii. Apply (+FS - 3/2 LSB) to channel 0. Values for the various instrumentation amplifier gain settings are shown below. Adjust the gain trimpot for an output code which flickers evenly between 4094 and 4095.

iii. Repeat the above two steps until no further adjustment is required.

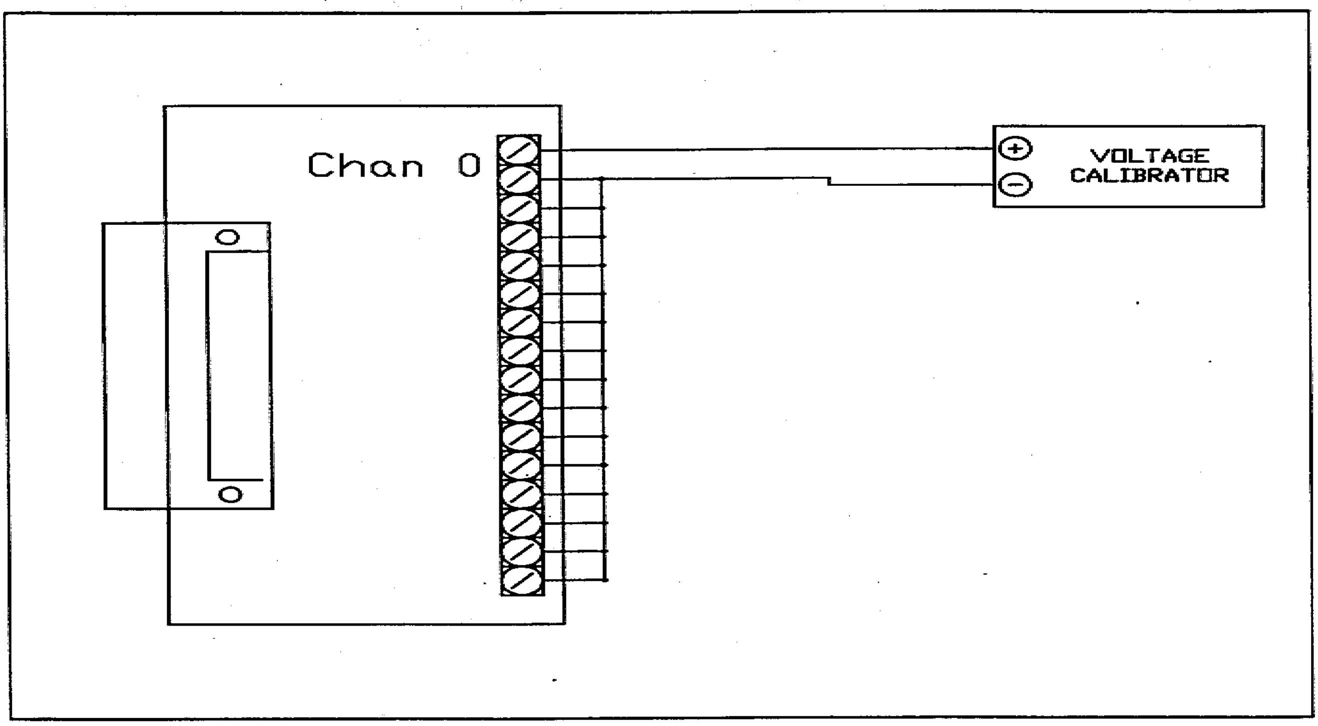

Figure 8.2. A/D calibration connections.

Gain	(+FS - 3/2 LSB)
1	4.0945 V
100	40.0945 mV
200	20.4725 mV
500	8.18900 mV

Table 8.1. Calibration voltage values.

8.3. A/D calibration Software

The program PC73.EXE, supplied on the distribution disk, allows the board to be calibrated by selecting the "Calibration" option in the main menu. Note that the PC73 program assumes that the default gain setting of 100 applies.

Appendix A

Hardware Specifications

I. Analog Input

1. Number of Input Channels

8 differential thermocouple, 1 cold junction compensation.

2. Resolution

12-bit plus sign, 1 in 8192

3. Total System Accuracy

+- 3 LSB

4. Differential Nonlinearity

+- 1/2 LSB max.

5. Quantization Uncertainty

+-1/2 LSB

6. Input Ranges

-4.095 to +4.095 V, -40.95 to +40.95 mV, -20.475 to +20.475 mV, -8.190 to +8.190 mV

7. Gain Drift

+- 30 ppm per degree C.

8. Offset Drift

+- 0.25 uV per degree C.

9. Input Impedance

1M/50 pF Off Chan typ.

1M/200 pF On Chan typ.

10. Offset Voltage

adjustable to zero.

11. Monotonicity

0 to 70 degree C

12. Data acquisition rate

30 Hz max.

II. Environmental

1. Operating Temperature

0 to 70 degrees C

2. Storage Temperature

-55 to 150 degrees C

3. Relative Humidity

5% to 95% noncondensing

III. PC Interface

1. Base Address

200 to 3FC, DIP switch selectable.

2. Number of registers

4 8-bit registers.

IV. Power

1. +5V

500 mA typ.

2. +12V

100 mA typ.

3. -12V

100 mA typ.

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Appendix B

Error Limits

This appendix discusses the accuracy of the PC-73 system, in conjunction with various thermocouples.

Note
The information in this appendix is for general guidance only; it does not represent guaranteed performance.

I. Error terms

Generally, the accuracy of a PC-73 system is dependent on three factors:

- The accuracy of the thermocouple.
- The accuracy of the PC-73 itself.
- The accuracy of the linearisation/cold junction compensation system used.

This appendix deals with all three of these.

II. Thermocouple error limits

Thermocouples are available to a wide variety of error limits, and you should contact your supplier for specific information on the thermocouples you are using. However, the various standards organizations publish error limits for so-called standard thermocouples. For NBS thermocouples, these are the following:

Type J	2.2 °C or 0.75%
Type K	2.2°C or 0.75% above 0°C, 2.2°C or 2.00% below 0°C

Type N	2.2°C or 0.75% above 0°C, 2.2°C or 2.00% below 0°C
Type E	1.7°C or 0.5% above 0°C, 1.7°C or 1.00% below 0°C
Type T	1.0°C or 0.75% above 0°C, 1.0°C or 1.5% below 0°C
Type R	1.5°C or 0.25%
Type S	1.5°C or 0.25%
Type B	1.5°C or 0.25%

III. PC-73 error limits

The effective error limits for the PC-73 depend on the gain setting, and the type of thermocouple. For the default gain setting of 100, the following figures provide a rough guide. At different gain settings, the error limits will be proportionally higher of lower.

Type J	0.2 °C above -100°C, 0.5°C below -100°C
Type K	0.2 °C above -100°C, 0.5°C below -100°C, 2°C below -200°C
Type N	0.25 °C above -100°C, 0.5°C below -100°C, 10°C below -200°C
Type E	0.2 °C above -200°C, 0.5°C below -200°C
Type T	0.25 °C above 0°C, 0.5°C below -100°C, 3°C below -200°C
Type S	1.2 °C above 350°C, 2°C below 350°C
Type R	1.2 °C above 350°C, 2°C below 350°C
Type B	1.2 °C above 1200°C, 2°C below 1200°C, 10°C below 600°C

In addition to these figures, the cold-junction compensation error of 1°C must be taken into account.

IV. Linearisation errors

Errors due to linearisation and cold junction compensation are dependent on the technique used. The figures below are for the segmented polynomial technique used in the supplied PC-73 software:

Type J	0.05°C above 0 °C, 0.1 °C below 0°C
Type K	0.1°C above 200 °C, 0.5 °C below 200°C, 3°C below -200 °C
Type N	0.1°C above -200 °C, 5°C below -200°C

Type E	0.1°C above -200 °C, 2.5°C below -200°C
Type T	0.1°C above -200 °C, 2.5°C below -200°C
Type S	0.2°C
Type R	0.2°C
Type B	0.2°C above 300 °C, 0.5°C below 300°C, not specified below 130°C

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Appendix C

Differences from previous versions

Previous versions of the PC-73 software made use of an offset measurement technique for negative temperatures. This required board offset to be set to a negative value. This offset technique is no longer used. Older boards calibrated for the old style software must be recalibrated to be able to use the software supplied with this manual. Calibration is performed by the PC73 program.

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Appendix D

Problem Determination Guide

I. Introduction

If you are experiencing problems, first check the following:

i. Remove the PC-73, and check that all ICs are firmly seated in their sockets, that there is no obvious damage to any components, and that the edge connector fingers on the PC-73 are clean.

ii. Check that the PC-73 is jumpered correctly for your application.

iii. Replace the PC-73, and check that it seats firmly in the host PC's mother-board. Also check that no components are touching an adjacent board.

iv. Check that the cable is securely plugged into the PC-73.

II. Common problems

1. PC-73 diagnostics report board not found.

This is typically as a result of incorrect DIP switch settings.

2. A/D output code all zeros or all ones.

This is typically as a result of floating inputs, or an overload.

If you have exceeded the maximum input voltage (+- 12 V), you may have damaged the input circuitry. If so, return the board to your dealer for repair.

3. A/D readings are noisy.

This may be as a result of one or more of several reasons:

i. Long leads.

ii. An electrically noisy environment

iii. Overloads on other input channels. Note also that if an input channels is overloaded it may saturate in such a way as to give a reading which appears to be in the normal range, but is very noisy.

4. The first reading in a series is inaccurate.

This is normally as a result of an overload on another input, or long leads.

Index