User Manual for PC73A

PC Based Thermocouple Temperature Measurement Card.

Low cost boards for IBM PC, XT, AT, PS/2 and compatible computers systems.

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1. Introduction

1.1 Overview

The PC73A is a low cost thermocouple measurement system for the IBM PC, PC/XT, PC/AT, PS/2 model 25, PS/2 model 30 and compatible computers. It is functionally compatible to the earlier PC73 thermocouple card but completely upgraded with new features and better noise performance.

The PC73A consists of two boards:

i] The main PC73A PC plug-in card which contains the ADC, digital logic and signal conditioning circuitry etc. This card connects directly into the PC's I/O bus.

ii] The PC73A Auxiliary card contains the cold-junction sensor and thermocouple screw-terminal input connectors. A separate calibration terminal is also on this card for calibrating the ADC. This board is connected to the main PC73A card via a 25 way screened cable.

1.2. Operating modes.

The PC73A can sample temperatures in two modes of operation. These are the POLLED MODE and the INTERRUPT MODE.

1.2.1 POLLED MODE.

In this mode all register read, write and ADC operations are directly controlled by software I/O instructions. The ADC status bit STS is polled to monitor ADC end-of-conversions. Running the PC73A in this mode is ideal if temperatures are continuously monitored and sampled in real time.

1.2.2. INTERRUPT MODE.

In this mode, on board counters are configured to trigger ADC conversions and a PC hardware interrupt signals an end of conversion. Applications and advantages of this mode are when temperatures are sampled over large time intervals eg every hour for the next two days. Running the PC73A in POLLED MODE is impractical, because the PC is inaccessible to the user for other applications over the two day sampling period. However if an INTERRUPT MODE program is made memory resident, the PC73A's I/O operations become invisible to the user which frees the PC for other applications.

1.3 Software.

Several C source code drivers are provided on diskette with the PC73A card. These drivers allow the user to control and run the PC73A using high level function calls when writing customised software. Furthermore it eliminates the need to understand the low-level architecture of the card. Also provided on diskette are pre-compiled executable files **CAL.EXE, INT.EXE** and **STP.EXE.** These programs allow the user to operate the PC73A directly from DOS in both modes without the need to write software.

2. Thermocouples

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. The temperature of the junction is derivable from this thermoelectric voltage.

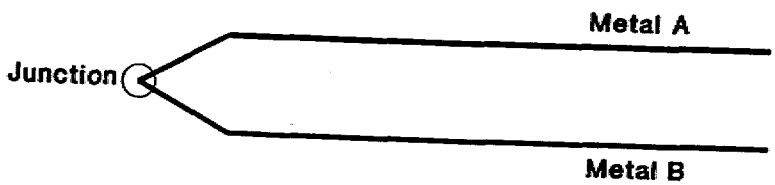

Figure 2.1. Thermocouple Junction.

The general characteristics of thermocouples are:

- **Accuracy:** 0.5°C to 5°C.

- **Temperature Range:** -200° to 1750°C.

- **Response Times:** 0.05 to 5 Seconds.

- **Size:** Robust and very small sizes available.

- **Power:** Not Required.

- **Output:** E.M.F. Generation.

- **Noise:** Susceptible.

- **Reference:** Required.

The above data is the average characteristics for thermocouples and should be interpreted with caution.

2.2. Cold-junction compensation.

A thermocouple sensors ambient temperature by producing across the junction a small voltage proportional to temperature. To measure that voltage, you must connect the thermocouples wires to an amplifier or voltmeter, creating two unwanted parasitic junctions that produce error voltages in series with the desired signal (figure 2.2). These parasitic junctions must have the same temperature. To interpret the thermocouple voltage as an absolute temperature signal, you need to maintain these parasitic junctions at a known temperature or compensate for their effect electronically. The thermocouple in effect measures temperature at its "hot" junction with respect to temperature at the two parasitic junctions - historically called the "cold" junction.

The term "cold-junction" derives from the practice of maintaining the parasitic junctions at 0°C by immersing them in a mixture of ice and water. Although very accurate, this approach is impractical for most application. A better approach, employs an electronic compensation circuit which tracks the cold-junction temperature instead of maintaining the junction at a constant temperature. The PC73A uses a LM35 temperature sensor to measure ambient (cold-junction) temperature and compensates for this offset in software.

Example.
Assume we have a type K thermocouple reading 23 millivolts, and the cold junction temperature is 21°C. What is the thermocouple temperature?

From thermocouple tables a type K thermocouple generates 0.838 millivolts at 21°C. Thus the measured temperature is 575°C which is the temperature for a type K thermocouple generating 23.838 millivolts.

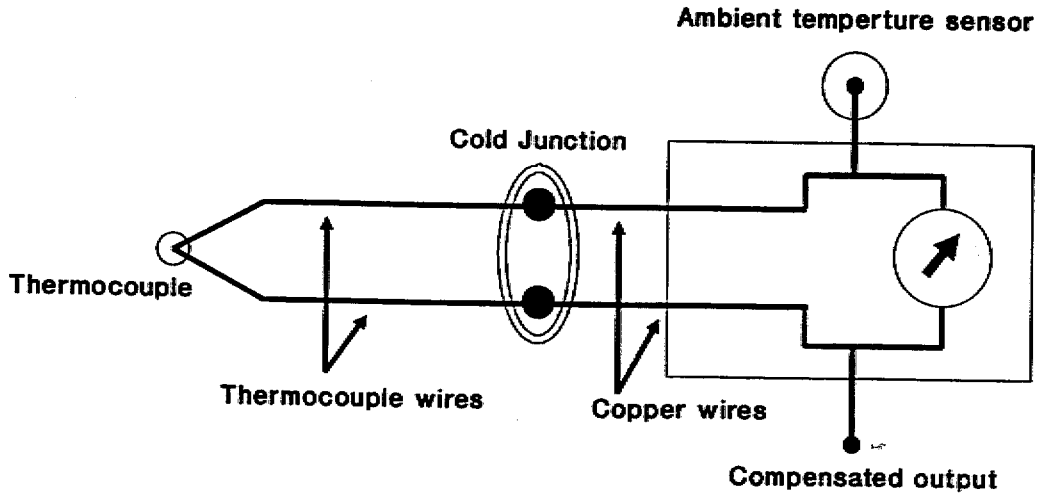

Figure 2.2. Thermocouple Measurements.

2.3. Temperatures from thermocouple voltages.

Thermocouples are non-linear transducers. Each thermocouple type has its own unique characteristic temperature versus voltage curve. For example a type J thermocouple has a thermal coefficient of 22 μvolts/°C at -200°C and 64 μvolts/°C at 750°C. Calculating temperatures from input thermocouple voltages and compensating for the non-linear behavior can be accomplished in hardware. However software techniques are generally easier and more practical to implement.

Two software methods most commonly used are:

- **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 "lookup" algorithm. The disadvantage of this method is the large memory storage required for saving the tables.

- **Polynomial compensation.** Using this technique, polynomial curves approximate each thermocouples temperature versus voltage characteristics. The order of the polynomial is dependent on the temperature range and the type of thermocouple used. For example type J thermocouples can be approximated to 0.1°C over a 0°C to 70°C temperature range using

a fifth order polynomial. A type E thermocouple however requires a ninth order polynomial for a 0.5°C accuracy.

For wide temperature ranges it is better to use several lower order polynomials over narrower temperature ranges. The PC73A driver software uses three eight order to convert voltages to temperatures for all thermocouples of type J, K, N, E, T, R, S and B. The range of each polynomial is optimised for each thermocouple type. Also the cold-junction sensors temperature input is converted to an equivalent thermocouple voltage using a second order polynomial and used for calculating the thermocouples absolute temperature.

2.4 Thermocouple standards.

Thermocouple standards specify the voltage versus temperature characteristics, colour codes, error limits and composition for standard thermocouples. There are five standards for thermocouples in use. These are:

- NBS (NIST)/ANSI- American. The American NBS standard is currently the most widely used. Colour codes are covered by ANSI and all make use of red negative leg colour codes. The PC73A thermocouple polynomial conversion curves are based on the NBS standard.

- BS - British. The British BS1843 standard makes use of blue negative leg codes.

- DIN - German. DIN 43714 thermocouples all make use of red positive leg colour coding.

- JIS - Japan. JIS C 1610-1981 thermocouples all make use of red positive leg/white negative leg colour coding.

- NF - French. NF C 42-323 thermocouples all make use of yellow positive leg colour coding.

Generally most thermocouple standards are interchangeable in terms of voltage versus temperature curves. The only exceptions are the DIN-J and DIN-T types.

Table 2.3. lists the extension and compensating lead insulation colour codes and standards for several thermocouple types.

Code:	Thermocouple	British BS1843:1952		American ANSI		German DIN	
E	Nickel-Chromium/ Copper-Nickel	Overall Brown		Overall Purple			
		Positive Brown	Negative Blue	Positive Purple	Negative Red		
J	Iron/Copper-Nickel	Overall Black		Overall Black		Overall Blue	
		Positive Yellow	Negative Blue	Positive White	Negative Red	Positive Red	Negative Blue
K	Nickel-Chromium/ Nickel-Aluminium	Overall Red		Overall Yellow		Overall Green	
		Positive Brown	Negative Blue	Positive Yellow	Negative Red	Positive Red	Negative Green
T	Copper/Copper-Nickel	Overall Blue		Overall Blue		Overall Brown	
		Positive White	Negative Blue	Positive Blue	Negative Red	Positive Red	Negative Brown
	Conductors						
U	Copper/Copper-Nickel compensating for S & R Platinum Rhodium/ Platinum 0-60°C range. Alternative names, Copper/ Cupronic, Cu/Cun. Copper/No. 11 Alloy	Overall Green		Overall Green		Overall White	
		Positive White	Negative Blue	Positive Black	Negative Red	Positive Red	Negative White
VX	Copper/Constantan (low Nickel) Alternative name, Cu/Constantan Compensating for 'K' over 0-80°C range	Overall Red		Overall Red		Overall Green	
		Positive White	Negative Blue	Positive Brown	Negative Red	Positive Red	Negative Green

Notes

(1) Extension Leads are made of the same materials as the thermocouples themselves as in the table 'E', 'J', 'K' and 'T' Compensating Leads are made of different materials to the thermocouples they work with but have similar thermal/EMF factors up to a temperature not exceeding 80°C as in the table 'U' and 'VX'.

(2) The use of 'T' wire instead of 'VX' compensating leads for 'K' can cause errors.

Table 2.3 Thermocouple compensation lead colour codes with standards.

You should establish from your supplier what standards your thermocouples conform and check for any deviations from the standard of your measuring instrument supports.

2.5. Thermocouple types and characteristics.

Eight thermocouple types are most widely used in industry. These thermocouples are divided into two groups: Base metal and Noble metal thermocouples.

2.5.1. Base metal thermocouples.

Base metal thermocouples are cheaper than noble metal types and are most commonly used. These thermocouples with the exception of type N do not have specified metal compositions but may be a combination of different metals that result in the appropriate voltage versus temperature curve. Examples are type J, K, N, E, T and S thermocouples.

2.5.2. Noble metal thermocouples.

Noble metal thermocouples all have similar characteristics. They are all platinum/rhodium types and more stable than base metal thermocouples. Normal operation is for measuring high temperatures. These thermocouples are often covered by a nonmetallic sheath that prevents vapor diffusion. Examples are type R and B thermocouples.

2.5.3 Other thermocouple types.

Other thermocouple types are available mostly in the form of exotic high temperature tungsten types. Eg type G, C and D thermocouples for measurements up to 2320°C.

Table 2.4 lists the characteristics and properties of several widely used thermocouple types, while Table 2.5 specifies the tolerances for certain temperature ranges.

Table 2.4 Properties of widely used thermocouples.

Conductor Combinations Positive Wire Named First	Code	Usual Continuous Operating Range	Millivolts Generated at 100°C, Reference Junction at 0°C	Relevant British Standard Table	Application Notes	Field Method of Identifying Positive and Negative Wires
Platinum - 10% Rhodium/Platinum also known as:— Le Chatelier Thermocouple	S	0 - 1400°C	0.645	BS4937 Part 1 1973	Requires ceramic protection tube in all atmospheres	Platinum (negative) is the softer wire
Platinum - 13% Rhodium/Platinum	R	0 - 1400°C	0.647	BS4937 Part 2 1973	Requires ceramic protection tube in all atmospheres	Platinum (negative) is the softer wire
Iron/Copper-Nickel Also known as:— Iron vs Constantan Fe vs Constantan	J	0 - 800°C	5.268	BS4937 Part 3 1973	Beware of oxidizing conditions and acids.	Iron (positive) is magnetic & rusts
Nickel-Chromium/ Nickel-Aluminium Also known as:— T1 vs T2, Cromel vs Alumel NiCr vs NiAl	K	0 - 1100°C	4.095	BS4937 Part 4 1973	Particularly suitable in oxidizing atmospheres Affected by reducing conditions - sulphur, cyanide, carbon, and hydrogen	Nickel-Aluminium (negative) is slightly magnetic
Copper/Copper Nickel Also known as:— Copper vs Constantan Copper vs Nickel	T	- 200 - 400°C	4.277	BS4937 Part 5 1974	Generally used for low and sub-zero temperatures	Copper (positive) by its colour
Nickel-Chromium/ Copper Nickel Also known as:— Nickel-Chromium vs Constantan Chromel vs Constantan Nickel vs Copper	E	0 - 800°C	6.137	BS4937 Part 6 1974	Not used in the U.K. as often as other base metal thermocouples but an accurate and stable thermocouple with high thermal EMF, especially at low temperatures	Heat the junction to a known temperature and check millivolt output against tables

Table 2.5. Thermocouple Tolerances. Reference junction at 0°C.

Tolerance Class	1	2	3
Tolerance values (±)	0.5°C or 0.004 (t)	1°C or 0.0075. (t)	1°C or 0.015. (t)
	Temperature limits for validity of tolerances		
Type T	-40°C to 350°C	-40°C to 350°C	-200°C to 40°C
Tolerance values (±)	1.5°C or 0.004. (t)	2.5°C or 0.0075. (t)	2.5°C or 0.015 (t)
	Temperature limits for validity of tolerances		
Type E	-40°C to 800°C	-40°C to 900°C	-200°C to 40°C
Type J	-40°C to 750°C	-40°C to 750°C	-
Type K	-40°C to 1000°C	-40°C to 1200°C	-200°C to 40°C
Tolerance values (±)	1°C (0 to 1100°C) or [1 + 0;003 (t-1100)] °C	1.5°C or 0.0025. (t)	4°C or 0.005. (t)
	Temperature limits for validity of tolerances		
Type R or S	0°C to 1600°C	0°C to 1600°C	-
Type B		600°C to 1700°C	600°C to 1700°C

Notes:

(1) (t) is the thermojunction temperature in °C

(2) The tolerance is expressed either as a deviation in degrees Celsius or as a percentage of the actual temperature. The greater value applies.

(3) Alternative names of conductors are given in table 4 with other conductor information.

(4) Thermocouple materials are normally supplied to specified tolerances at temperatures above 0°C.

For sub-zero temperature measurement (E, K and particularly T) tolerances should be agreed between user and manufacturer.

2.6 Thermocouple styles.

A thermocouples style is important in temperature measurements. Three styles are available as shown in figure 2.6.

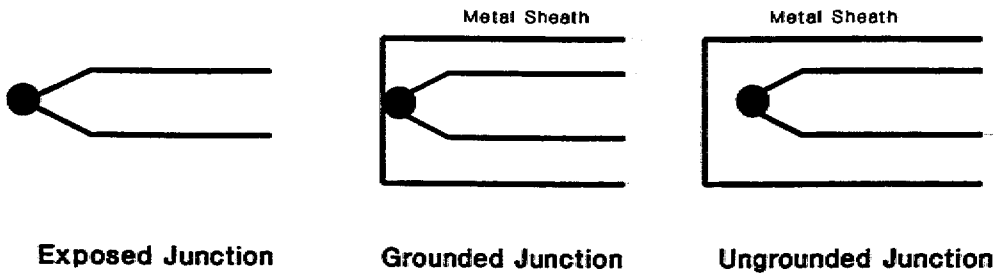

Figure 2.6 Thermocouple Styles.

2.6.1 Exposed junction.

The exposed or bead junction has its junction directly exposed to air. These thermocouples are recommended for measuring temperatures of static or non-corrosive gases and have fast thermal response times.

2.6.2. Ungrounded junction.

The thermocouple junction is protected and covered by a conductive sheath which is insulated from the thermocouple itself. Because of the electrical insulation around the junction, the thermal time response between sheath and junction is long, typically in the order of several minutes. The electrical insulation means it is safe to use these thermocouples in electrical systems that may be floating at different voltage levels to the PC.

2.6.3. Grounded junction.

The thermocouple junction is protected and connected electrically to a conductive sheath. The thermal response time is thus faster than ungrounded thermocouples. Disadvantages of this setup are:

i] Ground loops can occur

and

ii] Your PC is not electrically isolated from the apparatus it is measuring. Whenever grounded thermocouples are used for measuring temperatures in electrical systems it is important to check that the two systems are referenced to the same ground point. Failure to do so could result in a spectacular and catastrophic termination of your PC's life.

2.7. Using thermocouples.

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

2.7.1 Poor junction connections.

Poor junction connections are a prime cause of thermocouple problems. Errors of the orders of tens of °C can occur with thermocouple wires simple twisted together. More acceptable ways of forming the "hot" junction is using silver soldering or welding.

- Don't attempt to make up a thermocouple yourself. Amongst other problems, the junction can be contaminated and excessive heat can cause decalibration. It is recommended that commercially bought thermocouples always be used.

- Don't ever use twisted wires to form a thermocouple. this is almost guaranteed to result in substantial measurement errors.

- Never mix thermocouple wires or replace only one lead of a thermocouple. The two thermocouples of a particular batch are usually matched and the Constantin in a type J thermocouple is NOT the same as Constantin in a type T thermocouple.

2.7.2. Response times and length of insertion.

No general rule is available for thermocouple sensitivities although the smaller gauge wires types are suggested. Fine gauge unsheathed thermocouples are available with diameter ranges typically from 0.025mm to 0.81mm. This correlates to response times from 0.05 seconds to 40 seconds in still air.

Insufficient thermocouple insertion into the material being measured will result in low measurement readings. It is suggested that the thermocouples be inserted to a minimum of 4 times the outside diameter of the protective sheath to ensure that the correct temperature is measured.

2.7.3. Decalibration.

Decalibration results from unintentionally altering of the thermocouples physical makeup. Thus the thermocouples characteristics are permanently altered. 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 metal conduit.

- Annealing due to temperature gradients in different sections of the wire.

2.7.4. Galvanic action.

Atmospheric particles as well as the dyes used in some thermocouple insulations can form an electrolyte in the presence of water. This creates a galvanic junction resulting in an error in the thermocouples output voltage.

2.7.5 Noise.

It is important to NOTE that electrical and electromagnetic noise can result in substantial measurement errors when measuring low-level thermocouple signals. Using a PC to house the PC73A has numerous convenience and computational advantages, but a severe disadvantage in the noise it generates. The PC73A was specifically designed to minimise noise problems from the PC

environment. Noise reducing design features on the card include the use of numerous RF and RC filters and the complete separation of analogue and digital circuitry.

2.8 Further reading.

This chapter has provided a brief overview of thermocouples and their properties. Should you wish to learn more the following references are recommended:

1. Jim Williams, "Clever techniques improve thermocouple measurements", pages 145-160, EDN 26th May 1988.

2. Paul Horwitz and Winfield Hill, The Art of Electronics, Cambridge University Press, 2nd Edition 1982, USA, pages 592-594.

3. D.H. Sheingold, Nonlinear Circuits and Handbooks, Analog Devices Inc, Norwood, MA, 1974, pages 92-97.

4. "Manual on the use of thermocouples in temperature measurement", ASTM special publication #470A, American Society for Testing Materials, Philadelphia, PA, 1974.

5. "Thermocouple references tables", NBS monograph #125, National Bureau of Standards, Boulder, CO, 1975.

6. Jim Williams, "Designer's guide to temperature sensors", EDN. May 5, 1977, page 77.

3. Architecture.

The PC73A is a PC based temperature measuring system which uses thermocouple transducers to measure temperature. Up to eight thermocouples may be attached jointly on the external Auxiliary card which connects to the main PC based card via a 25-way screened cable.

3.1 Auxiliary card.

The Auxiliary card has three primary functions: These are:

i] Provide screw-terminal connectors for attaching up to eight thermocouples of different type.

ii] Positions the ambient temperature sensor (LM35) external to the PC. The LM35 provides thermocouple cold-junction compensation and is selected when 'AMBIENT' link L2 is inserted.

iii] Provides a calibration terminal for the ADC. This option is selected when the 'CALIBRATE' link L2 is inserted.

3.2. Analogue circuitry.

The analogue circuitry is located at the front end of the main PC73A card and is physically isolated from all digital circuitry for noise reduction. The eight input analogue channels are multiplexed to the inputs of an instrumentation amplifier. Switch SW3 sets the gain of the amplifier which is normally set to 100 for thermocouple applications. Link L1 provides a DC bias current path essential for thermocouple signals and should always be inserted. Low-pass LC and RC filters are placed on the inputs, outputs and power rails of the amplifier for improved noise performance. Trimpots VR1 to VR8 are used to trim the channel voltage offsets.

Amplified thermocouple signals from the instrumentation amplifier and the thermocouple cold-junction compensation input are multiplexed to the ADC analogue input.

3.3. Analogue to digital convertor.

The AD774 ADC allows a 11 bit plus 1 sign digital conversion of input thermocouple signals. Temperature data samples converted are read as two data bytes addressed as LDATA_73A and

HDATA_73A in the software drivers. Trimpots VR9 and VR10 provided adjustment for the ADC GAIN and bipolar OFFSETS. The maximum input voltage range for the ADC is ± 5 volts but it is set to ± 4.096 volts for the PC73A.

3.4. Digital circuitry.

The digital circuitry is physically isolated from the analogue circuitry to improve the PC73A's noise performance. A summary of digital functions are:

i] Set the base address of the PC73A.

ii] Provide registers for controlling and setting up the PC73A card. In the software drivers these registers are address as CHANN_73A (read only) and CNTRL_73A (read and write).

iii] Control batch and channel sampling timing during INTERRUPT MODE operations. DIP switch SW2 provides different timing divisions for the on-board 4.9152Mhz crystal which clocks the Intel 8254 counters. Counters 0 and 1 are connected in cascade and can be programmed to provide timing intervals from 5 seconds to several days. After the desired delay period, termed BATCH SAMPLING PERIOD, an ADC conversion will be initiated. Further ADC conversions can be initiated during a batch sample by configuring counter 2 to trigger the ADC from the interrupt servicing routine. This allows multi-sampling of a selected channel input or the sampling of all the eight channel inputs.

iv] Interface capabilities to activate the PC's hardware interrupts IRQ3, IRQ4, IRQ5 and IRQ7 during INTERRUPT MODE runs.

4. Getting started.

4.1 Hardware requirements:

i] A PERSONAL COMPUTER: IBM PC-XT/PC-AT, IBM PS-2/30, 386 or compatible personal computer with a monitor.

ii] HARD DISK DRIVE.

ii] Main PC73A card.

iii] Auxiliary card.

iv] A screened 25 way connector cable.

v] An adjustable +5 volts calibrated voltage source (resolution ± 1 millivolts) for calibration.

vi] At least one or up to eight thermocouples.

vi] A basic knowledge of electronic circuitry and measuring techniques.

4.2 Software requirements:

i] Operating system: MS-DOS or PC-DOS version 2.0 or later.

ii] PC73A driver and calibration software supplied on diskette.

iii] You are software literate in C and capable of writing your own programs.

See figure 4.1 for basic PC73A hardware configurations.

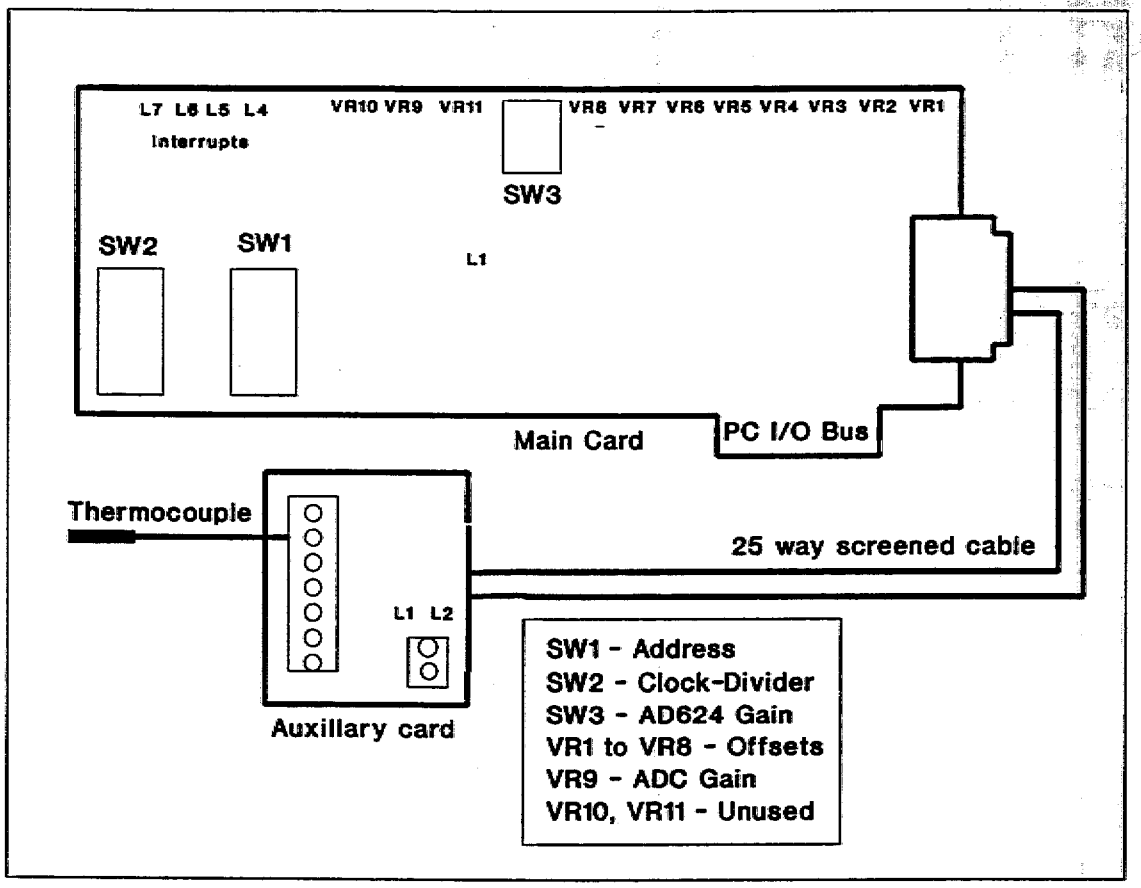

Figure 4.1 PC73A Hardware Configuration.

4.3 Setting up the PC73A hardware.

The PC73A can be configured to suit the users requirements. Hardware configurations should only be performed with the PC powered down and are selected by setting various jumpers and switches (figure 4.1). Check the following hardware settings before inserting the PC73A into your PC:

4.3.1 SW1. Setting the card address.

The base address of the card is set by using SW1. Addresses are set in hexidecimal by setting SW1 to the binary equivalent of the required card address (eg. $200 [(hex]) and increases in steps of eight. Eg $200, $208 etc... Note that the three least significant PC I/O address lines AD0, AD1 and AD2 are not accessible to the user. Thus the AD3 label next to the first switch on SW1 correlates to a binary weight of 8 in the address word. Examples of SW1 switch settings for valid card address are shown in figure 4.2.

Address (hex)	DIP Switch SW1 Setting						
	AD9	AD8	AD7	AD6	AD5	AD4	AD3
$0200	ON	OFF	OFF	OFF	OFF	OFF	OFF
$0208	ON	OFF	OFF	OFF	OFF	OFF	ON
$020C	ON	OFF	OFF	OFF	OFF	ON	ON
$0300	ON	ON	OFF	OFF	OFF	OFF	OFF
$0308	ON	ON	OFF	OFF	OFF	OFF	ON
$030C	ON	ON	OFF	OFF	OFF	ON	ON
$0380	ON	ON	ON	OFF	OFF	OFF	OFF

Figure 4.2 Valid PC73A Base Address SW1 Settings.

WARNING: Make sure that the PC73A addresses do not overlap with any other card address in your PC.

4.3.2 SW3. Setting the instrumentation amplifier gain.

The instrumentation amplifier gain is set by switching SW3 to the appropriate GAIN setting required.(figure 4.3). The default and most common gain is 100.

AD624 Gain	DIP SWITCH SW3 SETTING. sw4	sw3	sw2	sw1
1	OFF	OFF	OFF	ON
100	OFF	OFF	ON	OFF
200	OFF	ON	OFF	OFF
500	ON	OFF	OFF	OFF

Figure 4.3. AD624 Gain Settings for SW3.

4.3.3 Thermocouple current bias link L1.

Link L1 on the main PC73A main card provides a DC current bias path for thermocouples and should always be inserted.

4.3.4. Interrupt select links L4, L5, L6, and L7.

These links select a PC hardware interrupt for use with the INTERRUPT MODE. Only one link of the four should be inserted. The interrupts are selected as follows:

Link Number	Selected Interrupt
L4	IRQ3
L5	IRQ4
L6	IRQ5
L7	IRQ7

Figure 4.4. Link settings for hardware interrupts.

4.3.5. Auxiliary card links L1 and L2.

ONLY one link on the Auxiliary card should be inserted at any given time. The 'AMBIENT' link L2 selects the ambient sensor as an input to the ADC, while 'CALIBRATE' link L1 selects the calibration terminal as an input to the ADC.

WARNING: If both links L1 and L2 are inserted simultaneously while caliibrating the ADC, the LM35 sensor may be damaged or destroyed.

4.3.6 SW2. Clock-divider switch setting.

This switch is only used when the card is run in INTERRUPT MODE. The divide by 4096 option should be the ONLY switch ON.

4.3.7 Calibration trimpots.

The eight voltage trimpots VR1 to VR8 adjust each channels voltage offset to zero during calibration. Trimpots VR9 and VR10 adjust the ADC voltage GAIN and OFFSET when calibrating the ADC. See the chapter 7 on calibrating the PC73A for details.

4.3.8 Connecting up.

Once all the above hardware settings are correct, install the PC73A as follows:

i] Insert the main PC73A card into a free I/O slot in the PC.

ii] Connect the 25-way screened cable to the protruding DB25 male connector.

iii] Connect the female DB25 connector on the Auxiliary card to the other end of the screened cable.

iv] Attach thermocouples to the channel connector terminals on the Auxiliary card.

v] Connect a calibrated voltage source to the ADC calibration terminals if required.

4.4 Setting up the software.

You first create a sub-directory for the PC73A software and copy the supplied software to your HARD DISK. At the DOS prompt type the following:

C:> md PC73A < ENTER >

C:> cd PC73A < ENTER >

C:\PC73A> copy a:*.* < ENTER >

The following files are copied to the PC73A directory:

i] **PC73A.C** and **PC73A.H.** (General C Drivers).

ii] **EXAMPLES.C.** (Simple examples written in C++).

iii] **CAL.EXE.** (Used for calibrating the PC73A).

iv] **INT.EXE** and **STP.EXE.** (Run PC73A in INTERRUPT MODE).

To operate the PC73A you will have to study the manual chapter 6 "Software and Programming Guide" and the supplied C driver software. The compiled software files **CAL.EXE, INT.EXE** and **STP.EXE** are executable from DOS and allow the user to operate the PC73A without writing software.

5. Register structures.

Offset from Base Address	Register Name	Description
0	HDATA_73A	Read ADC MSB
1	LDATA_73A	Read ADC LSB
2	CHANN_73A	Selects Analogue channel input.
3	CNTRL_73A	Controls ADC and timers and read status of ADC.
4	COUNTER0	Intel 8254 Counter 0
5	COUNTER1	Intel 8254 Counter 1
6	COUNTER2	Intel 8254 Counter 2
7	CNTRL_COUNTERS	Intel 8254 Control Word

Figure 5.1 PC73A Register Structure.

5.1. Introduction.

This chapter describes the PC73A register structures for programming the card using low-level input and output I/O instructions. Note that high level source code drivers are provided with the PC73A so the user may skip this chapter if these drivers are adequate.

5.2. PC73A registers.

Choose the base address of the PC73A in the PC I/O space, with DIP switch SW1. Eight consecutive address locations from the base address are used by the card as shown in Figure 5.1.

5.3. HDATA_73A and LDATA_73A.

Analogue temperature voltage samples from the ADC have 11 bits plus one sign bit format. The 12 bit data sample is read in two operations from the HDATA_73A and LDATA_73A (figure 5.3) registers. ADC data is only available if the STS bit 0 in the CNTRL_73A register is high.

POL	AD10	AD9	AD8	AD7	AD6	AD5	AD4

HDATA_73A

AD3	AD2	AD1	AD0	XX	XX	XX	XX

LDATA_73A

Figure 5.3. PC73A DATA_73A Register Structure.

Most Significant Byte:
Data bits (AD4 to AD10) [Bits 0 to 6]. AD10 is the most significant bit of the MSB.
Polarity (POL) Bit 7. For positive ADC reading this bit is high (1). and for negative readings low (0).

Least Significant Byte:
Data Bits (AD3 to AD0) [Bits 4 to 7]. AD3 is the most significant bit of the LSB.
Reserved bits (Bits 0, 1 2 and 3) These bits are read as zero

5.4. CHANN_73A.

The CHANN_73A (figure 5.2) is an 8 bit write only register used by the PC73A to select the analogue channel input for ADC conversions. The contents of CHANN_73A are cleared on hardware reset.

XX	XX	XX	CJC	XX	CH2	CH1	CH0

Figure 5.2 PC73A CHANN_73A Register Structure

Channel Address Bits ([Ch2,Bit2], [CH1,Bit1], [CH0,Bit0]) These three bits in the CHANN_73A register select the analog channel for the next ADC conversion. These bits are only enabled if CJC bit 4 is zero. CH2 is the most significant bit.

Cold Junction Compensation (CJC) Bit 4. Setting the CJC bit high in the CHANN_73A register selects the ambient sensor voltage input as the next ADC conversion. This sensor measures the ambient room temperature for thermocouple cold-junction compensation. Resetting CJC to zero means the next ADC input is from the thermocouple channel selected by channel address bits CH2, CH1 and CH0.

CHANN-73A Reserved Bits (Bits 3, 5, 6, 7). These bits are reserved for future expansion and should be written as zeros for future compatibility.

5.5. CNTRL_73A.

The CNTRL_73A (figure 5.4) is an 8-bit read and write register which controls ADC conversions. Status information about the control bits is available when this register is read. All bits are cleared to zero on a PC reset.

XX	XX	XX	ET2	IE	C/R	/DT	BAC

WRITE ONLY

XX	XX	XX	XX	IE	C/R	/DT	STS

READ ONLY

Figure 5.4. PC73A CNTRL_73A Register Structure.

When writing to CNTRL_73A the bits are defined as follows:

Begin AUTO Conversion (BAC) Bit 0. After the PC73A on board counters have been configured for an INTERRUPT MODE run, setting this bit high starts the auto sampling process. The PC is interrupted after the desired BATCH SAMPLE PERIOD where channel data is sampled.

Disable Trigger (D/T) Bit 1. This bit is used to mask the batch sample trigger pulse after a batch sample is initiated during an INTERRUPT MODE run. An interrupt service routine would control I/O operations, data reads and additional ADC conversions using counter 2. This allows multiple samples of a single channel input or samples of the other seven channels to be taken. Once completed this bit is returned high and enables the triggering of a new batch sample after BATCH SAMPLE PERIOD.

Convert/Read (C/R) Bit 2. Controls ADC conversions and data reads during POLLED MODE operations. When this bit is high the ADC samples and converts the selected channels input analogue signal. When this bit is low and the STS bit is high the converted data may be read from HDATA_73A and LDATA_73A.

Interrupt Enable. (IE) Bit 4. The IE bit enables the selected hardware interrupt on the PC's I/O bus. The hardware interrupt is selected by inserting one of links L4, L5, L6 and L7 on the main PC73A card. Note the interrupts are tri-stated until the IE bit is set high. This bit should be set before the PC73A is run in INTERRUPT MODE and ONLY if the user has written an interrupt vector handling routine.

Enable counter 2 (EC2) Bit 4. Enables 8254 counter 2 when set high. This allows counter 2 to initiate ADC conversions during INTERRUPT MODE runs from the interrupt service routine.

CNTRL_73A Reserved Bits (Bits 5, 6, 7). These bits are reserved for future expansion and should be written as zeros for future compatibility.

When reading CNTRL_73A the bits are defined as follows:

ADC Status (STS) Bit 0. While an ADC conversion is in progress the STS bit is set low. After the ADC conversion has been completed and data from the conversion is ready, the STS bit is reset high. An end of conversion is indicated by monitoring this bit in the CNTRL_73A register during POLLED MODE runs. This bit is also used to trigger hardware interrupts during INTERRUPT MODE runs.

Status of /DT Bit 1. Reading this bit indicates the status of /DT.

Status of C/R Bit 2. Reading this bit indicates the status of C/R.

Status of IE Bit 3. Reading this bit indicates the status of IE.

Undefined Bits (Bits 4, 5, 6, 7). These bits are undefined when CNTRL_73A is read.

5.7. COUNTER0.

IC U14:- Intel 8254 Counter 0.

Counter Mode:- Set to Mode 2: Rate Generator.

Clock 0 Input:- Clock-divider crystal circuitry. Set by SW2.

Gate 0 Input:- Enabled when CNTRL_73A SAC bit set high.

Output 0:- Cascaded to input of Counter 1.

Function - Set BATCH SAMPLE PERIOD time delays when the PC73A is used in INTERRUPT MODE. Counter 0 and counter 1 are connected in cascade to give batch sampling periods from seconds to days. See the 8254 data sheet and software drivers for more details.

5.8. COUNTER1.

IC U14:- Intel 8254 Counter 1.

Counter Mode:- Set to Mode 2: Rate Generator.

Clock 1 Input:- Counter 0 output.

Gate 1 Input:- Enabled when CNTRL_73A SAC bit set high.

Output 1:- Connects to ADC R/C input through the GAL20V8.

Function - Set BATCH SAMPLE PERIOD time delays when the PC73A is used in INTERRUPT MODE. Counter 0 and counter 1 are connected in cascade to give batch sampling periods from seconds to days. The output of this counter is used to trigger the start of a batch sample after time BATCH SAMPLE PERIOD. See the 8254 data sheet and software drivers for more details.

5.9. COUNTER2.

IC U14:- Intel 8254 Counter 1.

Counter Mode:- Set to Mode 4: Software Retriggable One-shot.

Clock 2 Input:- Clock with frequency 154.75Khz.

Gate 2 Input:- Enabled when the CNTRL_73A EC2 bit 4 is set high.

Output 2:- Connected to the ADC R/C input through the GAL20v8.

Function:- Used to trigger new ADC conversions during a batch sample. Will normally be configured from an interrupt service routine to allow for multiple sampling of a single channel input (useful for averaging in high noise environments) or alternatively initiate ADC conversions on any of the eight channels. A minimum delay period of 200 milliseconds is required when switching between channels to allow for filter transient responses. See the 8254 data sheet and software drivers for more details.

5.10. CNTRL_COUNTER.

IC U14:- Intel 8254 Control Word.
Function:- Configure counters 0, 1, and 2. See the 8254 data sheet for more details.

6. Software and programming guide.

This chapter guides the reader in the necessary steps needed to program the PC73A for both modes of operation. High-level software drivers are provided in file **PC73A.C** on diskette with the PC73A and are described in this chapter. The driver software allows you to control the PC73A via high-level function calls without understanding the low-level operation of the card. It is strongly recommended that the user apply these drivers where possible or study the source code carefully when writing custom software for the PC73A. A file called **EXAMPLES.C** written in C is also supplied on diskette that gives simplified examples on how to configure the PC73A for the two modes of operation. Note the directive BC (see **PC73A.C**) should be defined when compiling with Borlandc C++, Turbo C etc and left undefined when compiling with Quick C and Microsoft C.

6.1. POLLED MODE.

This mode of operating the PC73A is ideal for continuous real time temperature measurements. The ADC is controlled from the CNTRL_73A using software I/O operations. An end of conversion is indicated by monitoring the STS bit in the CNTRL_73A. In this mode a dedicated PC program is required and the following software operations are necessary:

i] Initialise PC73A.

ii] Select channel for ADC input.

iii] Initiate an ADC conversion.

iv] When completed read the sampled data.

v] Convert ADC voltage data to temperature reading.

vi] Repeat steps ii to v for each channel and the ambient sensors input.

6.2. INTERRUPT MODE.

The advantage of using this mode is when temperature readings are sampled over large time intervals. Eg if you wished to sample channels 0, 1, 2, 3, 4, 5, 6, 7 every hour for a week. Using the POLLED MODE to operate the PC73A would mean the PC is tied up until sampling is

completed. With the INTERRUPT MODE option, the PC73A is configured to sample the selected channels independent of direct program control using hardware interrupts and timers. If this program is made memory resident the PC is free for alternative uses. The following software operations are required when configuring the PC73A for an INTERRUPT MODE run:

i] Initialise the PC73A.

ii] Configure the 8254 counters 0 and 1 to trigger a batch sample after the required BATCH SAMPLE PERIOD. In the above example the BATCH SAMPLE PERIOD is 1 hour.

iii] Write an interrupt service routine for the selected PC hardware interrupt. This routine would control ADC conversions and data reading during a batch sample. For example this routine could:

a] Read ADC sampled data and save to a DATA array.

b] Initiate multiple ADC conversions for each of the selected channels inputs say 200 μseconds apart. This is useful for averaging in high noise environments.

c] Initiate and control ADC conversions for the different selected input channels. A minimum switching period of 200 milliseconds is required when changing from channel to channel.

Of course the PC73A can operate in INTERRUPT MODE under a dedicated PC program. This would be particular useful with large programs where all data sampling can be controlled in the interrupt service routines. This frees the main program to perform alternative tasks and functions.

Because of the rather complex nature of writing software programs to run the PC73A in INTERRUPT MODE using a memory resident program, two executable programs are supplied on diskette that enable the user to run this mode from DOS without the need to write the software.

The program **INT.EXE** initates an INTERRUPT MODE run and remains resident in the PC's RAM allowing other application programs to be run concurrently. **CAL.EXE** should first be executed to calibrate the PC73A. The input parameter format for this program are:

INT [Address] [Interrupt Number] [BATCH SAMPLE PERIOD] [Number of Batch Samples] [Channel Sequence].

with:

i] **[Address]** - PC73A card address set by SW1 in hexidecimal.

ii] **[Interrupt Number]** - Select one of the PC hardware interrupts 3, 4, 5 or 7. Links L4, L5, L6 and L7 select the interrupt option on the PC73A card.

iii] **[BATCH SAMPLE PERIOD]** - Value in seconds in the range of 5 seconds to 40 days.

iv] **[Number of Batch Samples]** - Selects the number of batch samples each BATCH SAMPLE PERIOD apart. In the above example, number of batch samples = 1 (sample per hour) x 24 (hours per day) x 7 (days per week) = 168. During each batch sample, channels 0, 1, 2, 3, 4, 5, 6, 7 will be sampled. The ambient temperature sensor is also sampled automatically.

v] **[Channel Sequence]** - Enter the channel sampling sequence and order. A maximum of 8 channel numbers may be entered. Should you only wish to sample the ambient temperature this variable is not entered.

Examples of valid inputs are:

a] **INT 300 3 300 20 6 1 4.** An INTERRUPT MODE run is initiated with a PC73A card having address 300 hexidecimal and using hardware interrupt 3. Channels 6, 1, 4 and ambient are sampled every five minutes (300 seconds) for 1 hour (20 batch samples).

b] **INT 300 4 3600 24.** In this run example the ambient temperature is sampled every hour for 24 hours.

The program **STP.EXE** is used to halt an INTERRUPT MODE run initiated by **INT.EXE** prematurely/(when completed) and to download the sampled data to a DOS file **TEMP.DAT.** The format of the data download is raw ADC voltages which need to be converted to temperatures using function Voltstemp(). The program **INT.EXE** is removed from the PC's RAM after **STP.EXE** is used to halt the INTERRUPT MODE run.

Warning: When running application programs that also use interupts while **INT.EXE** is memory resident, system problems may be experienced. If this occurs select another interrupt.

6.3. C Drivers.

Driver software in C is provided on a diskette included with the PC73A card. The source file name is **PC73A.C** and the include file called **PC73A.H**. Compilation of the drivers with most C compilers should be possible. Note the directive BC must be defined when compiling **PC73A.C** with Borlandc C++, Turbo C etc and left undefined when compiling **PC73A.C** with Quick C and Microsoft C.

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

Include: <PC73A.H>

Function:
Initialises the PC73A card. The polynomial constants used to convert ADC data to temperature readings are also initialised in this module and which are used by function Volts2temp(). This function should be called before the PC73A in run in either of the two modes.

Input Variables:
i] int iBrd_num: Enter number from 0 to 7. Eight boards can reside in the PC at any one time.

ii] int iBrd_type; Enter PC73ABRD.

iii] int iBase_addr; Eg. enter $300 or any valid PC I/O space address.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or
ii] ERR_NOT_AVAIL - Board not found or faulty.

Low Level Coding:

6.3.2 int Ad_in(iBrd_num, iChan, ADC_Res);

Include: <PC73A.H>

MODE: POLLED MODE.

Function:
Gets a single ADC conversion from analogue input "iChan" on board "iBrd_num", and returns the voltage result "ADC_Res". The output voltage range is ±4095 millivolts. The ADC conversions are controlled directly from CNTRL_73A.

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

ii] int iChan; Enter value from 0 to 8. Note that values 0 to 7 refer to the analogue voltages from thermocouple channels 0 to 7. iChan = 8 refers to the ambient sensor voltage input.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or
ii] ERR_NOT_AVAIL - Board not found or faulty.

iii] int *ADC_Res: Raw analogue voltage reading obtained from ADC. Note that for open circuited channels (ie. no thermocouple attached) a value of -4095 millivolts is returned.

Low Level Coding:
i] Write the address of the channel you wish to obtain a sample voltage from to CHAN_73A.

ii] Delay at least 200 milliseconds to allow for low-pass filter transient response delays.

iii] Check STS bit in CNTL_73A is high. This means an ADC conversion may be initiated.

iv] Write $04 (hex) to CNTRL_73A register. This initiates the ADC to begin sampling the analogue voltage.

v] Wait for the STS bit in CNTRL_73A to return high. This means that a valid ADC conversion has occurred.

v] Write $00 to CNTRL_73A. This allows data to be read from HDATA_73A and LDATA_73A.

vi] Read the most significant data byte from HDATA_73A.

vii] Read the least significant data byte from LDATA_73A.

viii] Combine the two data bytes to calculate the count value in the range of ±2048 counts. Note 1 count correlates to 2 millivolts so multiply the count value by two to give a voltage reading in the range of ±4.095volts.

ix] Test polarity bit 7 of the most significant data byte. If high the result is positive otherwise negative.

x] For a more accurate reading in the presence of noise it is advisable to sample the channel signals several times and calculate the average count reading. Remember thermocouple voltage changes are in the μvolts range.

x] Return voltage reading *ADC_Res.

6.3.3 double Volts2temp(iThermo, dvolts, dtemp);

Include: <PC73A.H>

MODE: POLLED and INTERRUPT MODES.

Function:
Mathematically converts a thermocouple ADC sampled voltage and the ambient temperature to a thermocouple junction temperature in degrees Celsius. Uses the thermocouple polynomial curves initialised in function Init_brd();

Input Variables:
i] int iThermo: Thermocouple type that is being used to measure the temperature. Thermocouple types supported are J,K,E,T,B,R,S and N.

ii] double dvolts: Thermocouple analogue voltage [Volts] obtained from an ADC conversion.

iii] double *dTemp: Ambient temperature in degrees Celsius.

Return Variables:
i] double *dTemp: Thermocouple temperature in degrees Celsius.

Low Level Coding:
None.

6.3.4 int Temp_in(iBrd_num, iChan, iType, pdTemp);

Include: <PC73A.H>

MODE: POLLED MODE.

Function:
This module returns the thermocouple temperature pdTemp in Celsius from channel "iChan" on board "iBrd_num". This module performs high-level function calls to modules AD_in() and Volts2temp().

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

ii] int iChan: Enter value from 0 to 7. Note that values 0 to 7 refer to the analogue voltages from thermocouple channels 0 to 7.

iii] int iType: Thermocouple type that is being used to measure the temperature. Thermocouple types supported are J,K,E,T,B,R,S and N.

Return Variables:
i] double *pdTemp: Thermocouple temperature in degrees Celsius.

Low Level Coding:
None.

6.3.5. int set_batch_time(iBrd_num, clock_divider, batchtime);

Include: <PC73A.H>

Mode: INTERRUPT MODE.

Function:
This module sets up the BATCH SAMPLING PERIOD when running the PC73A in INTERRUPT MODE and triggers a batch sample. For example if temperature samples from channels 3, 2, 6, 7, 0, ambient is required every 2 hours apart, the batch sampling period is 7200 seconds. The BATCH SAMPLING PERIOD is dependent on the setting of SW2 which most commonly is set to the divide by 4096 option. The BATCH SAMPLING PERIOD is given by:

$$\frac{\text{CLOCK\_DIVIDER} * (\text{COUNTER0} - 1) * \text{COUNTER1}}{\text{CRYSTAL FREQUENCY}}$$

with:
a) clock_divider = 64, 128, 256, 512, 1024,..4096 set by SW2. Default and recommended setting is the divide by 4096 option.

b) Crystal frequency = 4.9152Mhz.

c) COUNTER0 is a value from 2 to 65536 loaded as a 16 bit word to register counter 0. This module selects COUNTER0 to have a minimum output clock period of 200 milliseconds and increments the value to allow for larger sampling periods.

d) COUNTER1 is a value from 2 to 65536 loaded as a 16 bit word to register counter 1.

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

ii] int clock_divider: Set by switch SW2 on the PC73A card.

iii] Batchtime: Time in seconds between successive batch samples.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or

ii] ERR_NOT_AVAIL - One of a) PC73A not found B) PC73A is faulty) PC73A not initialised or d) Batch sampling time requested with SW2 setting is impossible.

Low Level Coding:
Note the counter values are calculated from the SW2 setting with a minimum output clocking period for counter 0 of 200 milliseconds.

i] Determine count values for counter 0 and counter 1.

ii] Write $34 (hex) to CNTRL_TIMER. Sets up counter 0 to mode 2.

iii] Write lower count byte to COUNTER0.

iv] Write upper count byte to COUNTER0.

v] Write $74 (hex) to CNTRL_TIMER. Sets up counter 1 to mode 2.

vi] Write lower count byte to COUNTER1.

vii] Write upper count byte to COUNTER1.

6.3.6. int start_auto_conversion(iBrd_num);

Include: <PC73A.H>

Function:
After the PC73A counters have been configured to run in INTERRUPT MODE, this module starts the run. The card will now initiate a batch sample trigger after BATCH SAMPLE PERIOD. Batch triggers will continue until a software halt.

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or
ii] ERR_NOT_AVAIL - Board not found or faulty.

Low Level Coding:
i] Write $0B (hex) to CNTRL_73A.

6.3.7. int halt_auto_conversion(iBrd_num);

Include: <PC73A.H>

Function:
Halts batch sampling trigger pulses after the PC73A has run in INTERRUPT MODE.

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or
ii] ERR_NOT_AVAIL - Board not found or faulty.

Low Level Coding:
i] Write $00 (hex) to CNTRL_73A.

6.3.8 int ADC_in(iBrd_num, ADC_Res);

Include: <PC73A.H>

MODE: INTERRUPT MODE.

Function:
Reads the ADC data on board "iBrd_num" after a hardware interrupt and returns the voltage result "ADC_Res". The output voltage range is $\pm$4095 millivolts. This module will normally be called from the interrupt service routine. Note the channel from which data is sampled must be set up at least 200 milliseconds beforehand.

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or
ii] ERR_NOT_AVAIL - Board not found or faulty.

iii] int *ADC_Res: Raw analogue voltage reading obtained from ADC. Note that for open circuited channels (ie. no thermocouple attached) a value of -4095 millivolts is returned.

Low Level Coding:
i] Write $09 (hex) to CNTRL_73A. This masks the batch sample trigger pulse and allows data to be read from LDATA_73A and HDATA_73A.

ii] Read the most significant data byte from HDATA_73A.

iii] Read the least significant data byte from LDATA_73A.

iv] Combine the two data bytes to calculate the count value in the range of $\pm$2048 counts. Note 1 count correlates to 2 millivolts so multiply the count value by two to give a voltage reading in the range of $\pm$4.095volts.

v] Test polarity bit 7 of the most significant data byte. If high the result is positive otherwise negative.

vi] Return voltage reading *ADC_Res.

6.3.5. int init_ADC_sample(iBrd_num, count);

Include: <PC73A.H>

Mode: INTERRUPT MODE.

Function:
This module triggers an ADC conversion after (count * 32) / 4.9152 Mhz seconds. It should primarily be called during batch sampling from the interrupt service routine. Its function is to allow multiple sampling of a single channel input (useful for averaging in high noise environments) or to initiate ADC conversions on the other selected channel inputs. Note a delay

time of 200 milliseconds is required when switching between channels. The 8254 counter 2 is configured to mode 4 and is enabled by the EC2 bit in the CNTRL_73A register.

Input Variables:
i] int iBrd_num: Enter same board number as used when initialising the PC73A card.

ii] count: Range from 16 to 65535. The available delay_time is from 100 μseconds to 423 milliseconds.

Return Variables:
i] RETURN_OK - Board Initialised successfully.
or
ii] ERR_NOT_AVAIL - One of a) PC73A not found B) PC73A is faulty. c) PC73A not initialised.

Low Level Coding:
i] Write $19 (hex) to CNTRL_73A. Enables COUNTER 2.

i] Write $B8 (hex) to CNTRL_TIMER. Enables COUNTER 2 to mode 4. This configures COUNTER 2 to a mode 4 software triggered strobe counter.

iii] Write the lower count byte to COUNTER2.

iv] Write the upper count byte to COUNTER2. This starts the timing.

6.3.6. int set_int(int INTR);

Include: <PC73A.H>

Mode: INTERRUPT MODE.

Function:
Installs the interrupt service routine INT_handler for the selected hardware interrupt.

Input Variables:
i] int INTR: Select either IRQ3, IRQ4, IRQ5 or IRQ7.

6.3.7. int ret_int(int INTR);

Include: <PC73A.H>

Mode: INTERRUPT MODE.

Function:
Reinstalls the old interrupt service routine for the selected hardware interrupt.

Input Variables:
i] int INTR: Select either IRQ3, IRQ4, IRQ5 or IRQ7 as used in set_int().

6.3.6. void INTERRUPT INT_handler();

Include: <PC73A.H>

Mode: INTERRUPT MODE.

Function:
This module is an example of a typical interrupt service routine used for INTERRUPT MODE runs.

7. Calibrating the PC73A.

Program **CAL.EXE** is supplied on the distribution diskette and provides a user-friendly software tool for calibrating the PC73A.

7.1. Equipment required.

1] An adjustable calibrated 5 volts source. Resolution ±1mv or better.

2] Actual thermocouples that will be used for temperature sampling.

3] PC73A and Auxiliary cards.

4] Calibration program **CAL.EXE.**

7.2. Calibration procedure.

1] First read chapter 4 and ensure that you are familiar with all the hardware settings of the PC73A. We will assume the following hardware settings:

a) SW1 is set to address $300 (hex).

b) The AD624 gain switch SW3 is set to gain setting 100. (Most commonly used with thermocouples)

c) Link L1 on the main PC73A card is inserted.

d) Link L7 selecting IRQ7 on the main card is inserted.

e) SW2 is set to the divide by 4096 option.

2] On the DOS prompt type the following:

C:\PC73A CAL

3] Check the card status reads PC73A OKAY.

4] Steps 5 to 10 describe the procedure to calibrate the ADC. Note this procedure need not be performed every time the PC73A card is used.

5] Insert the 'CALIBRATE' link L1 on the Auxiliary card.The 'AMBIENT' link L2 should be removed. It is important that links L1 and L2 NEVER be inserted simultaneously while the ADC is being calibrated.

6] Attach a calibrated voltage source to the Auxiliary calibration terminal inputs.

7] Type 'C' from the main program screen to enter the ADC calibration option.

8] To calibrate the ADC OFFSET, apply 0 millivolts and adjust trimpot VR10, until the ADC output reading indicates 1 millivolts.

9] To calibrate the ADC GAIN apply an input voltage of 4093 milliVolts and adjust trimpot VR9 until the ADC output reading just indicates 4095 millivolts.

10] Steps 8 and 9 are interactive so these steps should be repeated several times until the ADC is calibrated.

11] Once the ADC is calibrated type 'ESC' to return to the main calibration screen.

12] Remove the calibration source. Insert the 'AMBIENT' link L2 on the Auxiliary card and remove the 'CALIBRATE' link L1.

13] Attach up to eight thermocouples to the appropriate thermocouple input channels. Note you need only attach thermocouples to the channels you will be using for measurements.

14] Ensure the channels are set up for the correct thermocouple type. Use the LEFT RIGHT UP and DOWN arrow keys to select different thermocouple type settings.

15] Adjust the CHANNEL OFFSET trimpots VR1 to VR8 for each of the channels until each VOLTAGE display output reads zero millivolts.

16] Repeat steps 15 for at least ten minutes until the PC73A reaches normal PC operating temperature.

7.3. Features of program CAL.EXE.

1] **CAL.EXE** also displays temperature readings for each channel so this program can be used for temperature measurements.

2] Should you wish to change the hardware base address setting of SW1, use the PC keyboard "+" and "-" keys to adjust the software settings until it correlates to SW1. If the PC73A is found, the message: "PC73A OKAY" will be displayed on the screen.

3] The thermocouple type for each channel can be adjusted by using the UP, DOWN, LEFT and RIGHT arrow keys.

4] The latest 'setup' configuration for **CAL.EXE** can be saved by pressing the 'S' key ie. thermocouple types and base address.

5] Type 'F1' to access the Help menu.

Appendix A

Hardware Specifications.

I. ANALOGUE INPUTS.

1. Number of input channels: 8

2. ADC resolution: 11 bits plus 1 sign bit.

3. Channel input impedance: > 10 Megohms.

4. Gain settings (SW3) and maximum input voltage ranges:

Gain	Voltage
1	±4.096 volts
100	±40.95 millivolts
200	±20.475 millivolts
500	±8.190 millivolts

5. Channel offset voltages: All channels adjustable to zero.

6. Data Acquisition Rate: 5Hz maximum.

7. Quantisation uncertainty: ±0.5 LSB (2 millivolts).

8. ADC GAIN: AD774 gain adjustable for an input voltage range of ±4.096 volts.

9. Open circuited thermocouple channels are biased to -4095 milliVolts.

II PC INTERFACE.

1. Base Address: Set by DIP switch SW1.

2. Number of registers: 8.

Offset from Base Address	Register Name	Description
0	HDATA_73A	Read ADC MSB
1	LDATA_73A	Read ADC LSB
2	CHANN_73A	Selects Analogue channel input.
3	CNTRL_73A	Controls ADC and timers and read status of ADC.
4	COUNTER0	Intel 8254 Counter 0
5	COUNTER1	Intel 8254 Counter 1
6	COUNTER2	Intel 8254 Counter 2
7	CNTRL_COUNTERS	Intel 8254 Control Word

III. POWER.

1. Digital: +5 volts from PC supply.

2. Analogue: ±12 volts from DC to DC convertor and linear regulators. Derived from PC +5 volts.

3. Current: Maximum of 100mA.

IV. GENERAL.

1. Temperature readings resolution $\pm$ 1°C dependent on noise and environment.

2. Two operating modes: POLLED MODE and INTERRUPT MODE.

3. PC73A printed circuit board designed for minimum noise rejection.

   - RC and LC Low-pass filters on analogue circuitry.

   - RF filters on power supplies.

   - Shielded cable connects Main and Auxiliary cards.

   - Analogue and digital circuitry separated.

4. Cold-junction compensation temperature range: 0°C - 70°C.

5. Link L1 on the main PC73A card should always be inserted. (provides DC current bias for thermocouples)

6. Link L2 on the Auxiliary card is used to connect the ambient sensor to the ADC.

7. Link L1 on the Auxiliary card is used to connect a calibrated voltage source to the ADC.

8. Links L4, L5, L6, L7 select PC hardware interrupts IRQ3, IRQ4, IRQ5 and IRQ7.

Appendix B

Thermocouple Tables.

Temperature / Millivolts Equivalents.

USE OF TEMPERATURE EMF TABLES FOR THERMOCOUPLES

For the observed EMF output from a measuring thermocouple with the reference temperature at 0°C, the equivalent temperature can be read directly from the appropriate table.

If the reference temperature differs from 0°C, the actual reference temperature should be measured by a mercury-in-glass thermometer in close proximity, and the equivalent EMF from the tables algebraically added to the observed measuring junction EMF. This gives the EMF that the thermocouple would produce if the reference junction were at 0°C.

Example:

Observed type K thermocouple output	15.597 mV
Reference temperature measured as 20°C, millivolt equivalent from K tables	0.798 mV
Corrected output	16.395 mV

From the K tables, this is equivalent to 400°C.

Type S Thermocouples. Pt10% Rh - Pt

Temperature Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
					THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS							
-50	-0.236											-50
-40	-0.194	-0.199	-0.203	-0.207	-0.211	-0.215	-0.220	-0.224	-0.228	-0.232	-0.236	-40
-30	-0.150	-0.155	-0.159	-0.164	-0.168	-0.173	-0.177	-0.181	-0.186	-0.190	-0.194	-30
-20	-0.103	-0.108	-0.112	-0.117	-0.122	-0.127	-0.132	-0.136	-0.141	-0.145	-0.150	-20
-10	-0.053	-0.058	-0.063	-0.068	-0.073	-0.078	-0.083	-0.088	-0.093	-0.098	-0.103	-10
- 0	0.000	-0.005	-0.011	-0.016	-0.021	-0.027	-0.032	-0.037	-0.042	-0.048	-0.053	- 0
0	0.000	0.005	0.011	0.016	0.022	0.027	0.033	0.038	0.044	0.050	0.055	0
10	0.055	0.061	0.067	0.072	0.078	0.084	0.090	0.095	0.101	0.107	0.113	10
20	0.113	0.119	0.125	0.131	0.137	0.142	0.148	0.154	0.161	0.167	0.173	20
30	0.173	0.179	0.185	0.191	0.197	0.203	0.210	0.216	0.222	0.228	0.235	30
40	0.235	0.241	0.247	0.254	0.260	0.266	0.273	0.279	0.286	0.292	0.299	40
50	0.299	0.305	0.312	0.318	0.325	0.331	0.338	0.345	0.351	0.358	0.365	50
60	0.365	0.371	0.378	0.385	0.391	0.398	0.405	0.412	0.419	0.425	0.432	60
70	0.432	0.439	0.446	0.453	0.460	0.467	0.474	0.481	0.488	0.495	0.502	70
80	0.502	0.509	0.516	0.523	0.530	0.537	0.544	0.551	0.558	0.566	0.573	80
90	0.573	0.580	0.587	0.594	0.602	0.609	0.616	0.623	0.631	0.638	0.645	90
100	0.645	0.653	0.660	0.667	0.675	0.682	0.690	0.697	0.704	0.712	0.719	100
110	0.719	0.727	0.734	0.742	0.749	0.757	0.764	0.772	0.780	0.787	0.795	110
120	0.795	0.802	0.810	0.818	0.825	0.833	0.841	0.848	0.856	0.864	0.872	120
130	0.872	0.879	0.887	0.895	0.903	0.910	0.918	0.926	0.934	0.942	0.950	130
140	0.950	0.957	0.965	0.973	0.981	0.989	0.997	1.005	1.013	1.021	1.029	140
150	1.029	1.037	1.045	1.053	1.061	1.069	1.077	1.085	1.093	1.101	1.109	150
160	1.109	1.117	1.125	1.133	1.141	1.149	1.158	1.166	1.174	1.182	1.190	160
170	1.190	1.198	1.207	1.215	1.223	1.231	1.240	1.248	1.256	1.264	1.273	170
180	1.273	1.281	1.289	1.297	1.306	1.314	1.322	1.331	1.339	1.347	1.356	180
190	1.356	1.364	1.373	1.381	1.389	1.398	1.406	1.415	1.423	1.432	1.440	190
200	1.449	1.448	1.457	1.465	1.474	1.482	1.491	1.499	1.508	1.516	1.525	200
210	1.525	1.534	1.542	1.551	1.559	1.568	1.576	1.585	1.594	1.602	1.611	210
220	1.611	1.620	1.628	1.637	1.645	1.654	1.663	1.671	1.680	1.689	1.698	220
230	1.698	1.706	1.715	1.724	1.732	1.741	1.750	1.759	1.767	1.776	1.785	230
240	1.785	1.794	1.802	1.811	1.820	1.829	1.838	1.846	1.855	1.864	1.873	240
250	1.873	1.882	1.891	1.899	1.908	1.917	1.926	1.935	1.944	1.953	1.962	250
260	1.962	1.971	1.979	1.988	1.997	2.006	2.015	2.024	2.033	2.042	2.051	260
270	2.051	2.060	2.069	2.078	2.087	2.096	2.105	2.114	2.123	2.132	2.141	270
280	2.141	2.150	2.159	2.168	2.177	2.186	2.195	2.204	2.213	2.222	2.232	280
290	2.232	2.241	2.250	2.259	2.268	2.277	2.286	2.295	2.304	2.314	2.323	290
300	2.323	2.332	2.341	2.350	2.359	2.368	2.378	2.387	2.396	2.405	2.414	300
310	2.414	2.424	2.433	2.442	2.451	2.460	2.470	2.479	2.488	2.497	2.506	310
320	2.506	2.516	2.525	2.534	2.543	2.553	2.562	2.571	2.581	2.590	2.599	320
330	2.599	2.608	2.618	2.627	2.636	2.646	2.655	2.664	2.674	2.683	2.692	330
340	2.692	2.702	2.711	2.720	2.730	2.739	2.748	2.758	2.767	2.776	2.786	340
350	2.786	2.795	2.805	2.814	2.823	2.833	2.842	2.852	2.861	2.870	2.880	350
360	2.880	2.889	2.899	2.908	2.917	2.927	2.936	2.946	2.955	2.965	2.974	360
370	2.974	2.984	2.993	3.003	3.012	3.022	3.031	3.041	3.050	3.059	3.069	370
380	3.069	3.078	3.088	3.097	3.107	3.117	3.126	3.136	3.145	3.155	3.164	380
390	3.164	3.174	3.183	3.193	3.202	3.212	3.221	3.231	3.241	3.250	3.260	390
400	3.260	3.269	3.279	3.288	3.298	3.308	3.317	3.327	3.336	3.346	3.356	400
410	3.356	3.365	3.375	3.384	3.394	3.404	3.413	3.423	3.433	3.442	3.452	410
420	3.452	3.462	3.471	3.481	3.491	3.500	3.510	3.520	3.529	3.539	3.549	420
430	3.549	3.558	3.568	3.578	3.587	3.597	3.607	3.616	3.626	3.636	3.645	430
440	3.645	3.655	3.665	3.675	3.684	3.694	3.704	3.714	3.723	3.733	3.743	440
450	3.743	3.752	3.762	3.772	3.782	3.791	3.801	3.811	3.821	3.831	3.840	450
460	3.840	3.850	3.860	3.870	3.879	3.889	3.899	3.909	3.919	3.928	3.938	460
470	3.938	3.948	3.958	3.968	3.977	3.987	3.997	4.007	4.017	4.027	4.036	470
480	4.036	4.046	4.056	4.066	4.076	4.086	4.095	4.105	4.115	4.125	4.135	480
490	4.135	4.145	4.155	4.164	4.174	4.184	4.194	4.204	4.214	4.224	4.234	490
500	4.234	4.243	4.253	4.263	4.273	4.283	4.293	4.303	4.313	4.323	4.333	500
510	4.333	4.343	4.352	4.362	4.372	4.382	4.392	4.402	4.412	4.422	4.432	510
520	4.432	4.442	4.452	4.462	4.472	4.482	4.492	4.502	4.512	4.522	4.532	520
530	4.532	4.542	4.552	4.562	4.572	4.582	4.592	4.602	4.612	4.622	4.632	530
540	4.632	4.642	4.652	4.662	4.672	4.682	4.692	4.702	4.712	4.722	4.732	540
550	4.732	4.742	4.752	4.762	4.772	4.782	4.792	4.802	4.812	4.822	4.832	550
560	4.832	4.842	4.852	4.862	4.873	4.883	4.893	4.903	4.913	4.923	4.933	560
570	4.933	4.943	4.953	4.963	4.973	4.984	4.994	5.004	5.014	5.024	5.034	570
580	5.034	5.044	5.054	5.065	5.075	5.085	5.095	5.105	5.115	5.125	5.136	580
590	5.136	5.146	5.156	5.166	5.176	5.186	5.197	5.207	5.217	5.227	5.237	590
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type R Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS											
1.250	13.922	13.936	13.950	13.964	13.978	13.992	14.006	14.020	14.034	14.048	14.062	1.250
1.260	14.062	14.076	14.090	14.104	14.118	14.132	14.146	14.160	14.174	14.188	14.202	1.260
1.270	14.202	14.216	14.230	14.244	14.258	14.272	14.286	14.301	14.315	14.329	14.343	1.270
1.280	14.343	14.357	14.371	14.385	14.399	14.413	14.427	14.441	14.455	14.469	14.483	1.280
1.290	14.483	14.497	14.511	14.525	14.539	14.554	14.568	14.582	14.596	14.610	14.624	1.290
1.300	14.624	14.638	14.652	14.666	14.680	14.694	14.708	14.722	14.737	14.751	14.765	1.300
1.310	14.765	14.779	14.793	14.807	14.821	14.835	14.849	14.863	14.877	14.891	14.906	1.310
1.320	14.906	14.920	14.934	14.948	14.962	14.976	14.990	15.004	15.018	15.032	15.047	1.320
1.330	15.047	15.061	15.075	15.089	15.103	15.117	15.131	15.145	15.159	15.173	15.188	1.330
1.340	15.188	15.202	15.216	15.230	15.244	15.258	15.272	15.286	15.300	15.315	15.329	1.340
1.350	15.329	15.343	15.357	15.371	15.385	15.399	15.413	15.427	15.442	15.456	15.470	1.350
1.360	15.470	15.484	15.498	15.512	15.526	15.540	15.555	15.569	15.583	15.597	15.611	1.360
1.370	15.611	15.625	15.639	15.653	15.667	15.682	15.696	15.710	15.724	15.738	15.752	1.370
1.380	15.752	15.766	15.780	15.795	15.809	15.823	15.837	15.851	15.865	15.879	15.893	1.380
1.390	15.893	15.908	15.922	15.936	15.950	15.964	15.978	15.992	16.006	16.021	16.035	1.390
1.400	16.035	16.049	16.063	16.077	16.091	16.105	16.119	16.134	16.148	16.162	16.176	1.400
1.410	16.176	16.190	16.204	16.218	16.232	16.247	16.261	16.275	16.289	16.303	16.317	1.410
1.420	16.317	16.331	16.345	16.360	16.374	16.388	16.402	16.416	16.430	16.444	16.458	1.420
1.430	16.458	16.472	16.487	16.501	16.515	16.529	16.543	16.557	16.571	16.585	16.599	1.430
1.440	16.599	16.614	16.628	16.642	16.656	16.670	16.684	16.698	16.712	16.726	16.741	1.440
1.450	16.741	16.755	16.769	16.783	16.797	16.811	16.825	16.839	16.853	16.867	16.882	1.450
1.460	16.882	16.896	16.910	16.924	16.938	16.952	16.966	16.980	16.994	17.008	17.022	1.460
1.470	17.022	17.037	17.051	17.065	17.079	17.093	17.107	17.121	17.135	17.149	17.163	1.470
1.480	17.163	17.177	17.192	17.206	17.220	17.234	17.248	17.262	17.276	17.290	17.304	1.480
1.490	17.304	17.318	17.332	17.346	17.360	17.374	17.388	17.402	17.417	17.431	17.445	1.490
1.500	17.445	17.459	17.473	17.487	17.501	17.515	17.529	17.543	17.557	17.571	17.585	1.500
1.510	17.585	17.599	17.613	17.627	17.641	17.655	17.669	17.684	17.698	17.712	17.726	1.510
1.520	17.726	17.740	17.754	17.768	17.782	17.796	17.810	17.824	17.838	17.852	17.866	1.520
1.530	17.866	17.880	17.894	17.908	17.922	17.936	17.950	17.964	17.978	17.992	18.006	1.530
1.540	18.006	18.020	18.034	18.048	18.062	18.076	18.090	18.104	18.118	18.132	18.146	1.540
1.550	18.146	18.160	18.174	18.188	18.202	18.216	18.230	18.244	18.258	18.272	18.286	1.550
1.560	18.286	18.299	18.313	18.327	18.341	18.355	18.369	18.383	18.397	18.411	18.425	1.560
1.570	18.425	18.439	18.453	18.467	18.481	18.495	18.509	18.523	18.537	18.550	18.564	1.570
1.580	18.564	18.578	18.592	18.606	18.620	18.634	18.648	18.662	18.676	18.690	18.703	1.580
1.590	18.703	18.717	18.731	18.745	18.759	18.773	18.787	18.801	18.815	18.828	18.842	1.590
1.600	18.842	18.856	18.870	18.884	18.898	18.912	18.926	18.939	18.953	18.967	18.981	1.600
1.610	18.981	18.995	19.009	19.023	19.036	19.050	19.064	19.078	19.092	19.106	19.119	1.610
1.620	19.119	19.133	19.147	19.161	19.175	19.188	19.202	19.216	19.230	19.244	19.257	1.620
1.630	19.257	19.271	19.285	19.299	19.313	19.326	19.340	19.354	19.368	19.382	19.395	1.630
1.640	19.395	19.409	19.423	19.437	19.450	19.464	19.478	19.492	19.505	19.519	19.533	1.640
1.650	19.533	19.547	19.560	19.574	19.588	19.602	19.615	19.629	19.643	19.656	19.670	1.650
1.660	19.670	19.684	19.698	19.711	19.725	19.739	19.752	19.766	19.780	19.793	19.807	1.660
1.670	19.807	19.821	19.834	19.848	19.862	19.875	19.889	19.903	19.916	19.930	19.944	1.670
1.680	19.944	19.957	19.971	19.985	19.998	20.012	20.025	20.039	20.053	20.066	20.080	1.680
1.690	20.080	20.093	20.107	20.120	20.134	20.148	20.161	20.175	20.188	20.202	20.215	1.690
1.700	20.215	20.229	20.242	20.256	20.269	20.283	20.296	20.309	20.323	20.336	20.350	1.700
1.710	20.350	20.363	20.377	20.390	20.403	20.417	20.430	20.443	20.457	20.470	20.483	1.710
1.720	20.483	20.497	20.510	20.523	20.537	20.550	20.563	20.576	20.590	20.603	20.616	1.720
1.730	20.616	20.629	20.642	20.656	20.669	20.682	20.695	20.708	20.721	20.734	20.748	1.730
1.740	20.748	20.761	20.774	20.787	20.800	20.813	20.826	20.839	20.852	20.865	20.878	1.740
1.750	20.878	20.891	20.904	20.916	20.929	20.942	20.955	20.968	20.981	20.994	21.006	1.750
1.760	21.006	21.019	21.032	21.045	21.057	21.070	21.083	21.096	21.108			1.760
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type B Thermocouples, Pt30% Rh - Pt 6% Rh

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS											
0	0.000	-0.000	-0.000	-0.001	-0.001	-0.001	-0.001	-0.001	-0.002	-0.002	-0.002	0
10	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.003	-0.003	-0.003	10
20	-0.003	-0.003	-0.003	-0.003	-0.003	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	20
30	-0.002	-0.002	-0.002	-0.002	-0.002	-0.001	-0.001	-0.001	-0.001	-0.001	-0.000	30
40	-0.000	-0.000	-0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.002	40
50	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.006	0.006	50
60	0.006	0.007	0.007	0.008	0.008	0.009	0.009	0.010	0.010	0.011	0.011	60
70	0.011	0.012	0.012	0.013	0.014	0.014	0.015	0.015	0.016	0.017	0.017	70
80	0.017	0.018	0.019	0.020	0.020	0.021	0.022	0.022	0.023	0.024	0.025	80
90	0.025	0.026	0.026	0.027	0.028	0.029	0.030	0.031	0.031	0.032	0.033	90
100	0.033	0.034	0.035	0.036	0.037	0.038	0.039	0.040	0.041	0.042	0.043	100
110	0.043	0.044	0.045	0.046	0.047	0.048	0.049	0.050	0.051	0.052	0.053	110
120	0.053	0.055	0.056	0.057	0.058	0.059	0.060	0.062	0.063	0.064	0.065	120
130	0.065	0.066	0.068	0.069	0.070	0.071	0.073	0.074	0.075	0.077	0.078	130
140	0.078	0.079	0.081	0.082	0.083	0.085	0.086	0.088	0.089	0.091	0.092	140
150	0.092	0.093	0.095	0.096	0.098	0.099	0.101	0.102	0.104	0.106	0.107	150
160	0.107	0.109	0.110	0.112	0.113	0.115	0.117	0.118	0.120	0.122	0.123	160
170	0.123	0.125	0.127	0.128	0.130	0.132	0.133	0.135	0.137	0.139	0.140	170
180	0.140	0.142	0.144	0.146	0.148	0.149	0.151	0.153	0.155	0.157	0.159	180
190	0.159	0.161	0.163	0.164	0.166	0.168	0.170	0.172	0.174	0.176	0.178	190
200	0.178	0.180	0.182	0.184	0.186	0.188	0.190	0.192	0.194	0.197	0.199	200
210	0.199	0.201	0.203	0.205	0.207	0.209	0.211	0.214	0.216	0.218	0.220	210
220	0.220	0.222	0.225	0.227	0.229	0.231	0.234	0.236	0.238	0.240	0.243	220
230	0.243	0.245	0.247	0.250	0.252	0.254	0.257	0.259	0.262	0.264	0.266	230
240	0.266	0.269	0.271	0.274	0.276	0.279	0.281	0.284	0.286	0.289	0.291	240
250	0.291	0.294	0.296	0.299	0.301	0.304	0.307	0.309	0.312	0.314	0.317	250
260	0.317	0.320	0.322	0.325	0.328	0.330	0.333	0.336	0.338	0.341	0.344	260
270	0.344	0.347	0.349	0.352	0.355	0.358	0.360	0.363	0.366	0.369	0.372	270
280	0.372	0.375	0.377	0.380	0.383	0.386	0.389	0.392	0.395	0.398	0.401	280
290	0.401	0.404	0.406	0.409	0.412	0.415	0.418	0.421	0.424	0.427	0.431	290
300	0.431	0.434	0.437	0.440	0.443	0.446	0.449	0.452	0.455	0.458	0.462	300
310	0.462	0.465	0.468	0.471	0.474	0.477	0.481	0.484	0.487	0.490	0.494	310
320	0.494	0.497	0.500	0.503	0.507	0.510	0.513	0.517	0.520	0.523	0.527	320
330	0.527	0.530	0.533	0.537	0.540	0.544	0.547	0.550	0.554	0.557	0.561	330
340	0.561	0.564	0.568	0.571	0.575	0.578	0.582	0.585	0.589	0.592	0.596	340
350	0.596	0.599	0.603	0.606	0.610	0.614	0.617	0.621	0.625	0.628	0.632	350
360	0.632	0.636	0.639	0.643	0.647	0.650	0.654	0.658	0.661	0.665	0.669	360
370	0.669	0.673	0.677	0.680	0.684	0.688	0.692	0.696	0.699	0.703	0.707	370
380	0.707	0.711	0.715	0.719	0.723	0.727	0.730	0.734	0.738	0.742	0.746	380
390	0.746	0.750	0.754	0.758	0.762	0.766	0.770	0.774	0.778	0.782	0.786	390
400	0.786	0.790	0.794	0.799	0.803	0.807	0.811	0.815	0.819	0.823	0.827	400
410	0.827	0.832	0.836	0.840	0.844	0.848	0.853	0.857	0.861	0.865	0.870	410
420	0.870	0.874	0.878	0.882	0.887	0.891	0.895	0.900	0.904	0.908	0.913	420
430	0.913	0.917	0.921	0.926	0.930	0.935	0.939	0.943	0.948	0.952	0.957	430
440	0.957	0.961	0.966	0.970	0.975	0.979	0.984	0.988	0.993	0.997	1.002	440
450	1.002	1.006	1.011	1.015	1.020	1.025	1.029	1.034	1.039	1.043	1.048	450
460	1.048	1.052	1.057	1.062	1.066	1.071	1.076	1.081	1.085	1.090	1.095	460
470	1.095	1.099	1.104	1.109	1.114	1.119	1.123	1.128	1.133	1.138	1.143	470
480	1.143	1.148	1.152	1.157	1.162	1.167	1.172	1.177	1.182	1.187	1.192	480
490	1.192	1.197	1.202	1.206	1.211	1.216	1.221	1.226	1.231	1.236	1.241	490
500	1.241	1.246	1.252	1.257	1.262	1.267	1.272	1.277	1.282	1.287	1.292	500
510	1.292	1.297	1.303	1.308	1.313	1.318	1.323	1.328	1.334	1.339	1.344	510
520	1.344	1.349	1.354	1.360	1.365	1.370	1.375	1.381	1.386	1.391	1.397	520
530	1.397	1.402	1.407	1.413	1.418	1.423	1.429	1.434	1.439	1.445	1.450	530
540	1.450	1.455	1.461	1.467	1.472	1.477	1.483	1.488	1.494	1.499	1.505	540
550	1.505	1.510	1.516	1.521	1.527	1.532	1.538	1.544	1.549	1.555	1.560	550
560	1.560	1.566	1.571	1.577	1.583	1.588	1.594	1.600	1.605	1.611	1.617	560
570	1.617	1.622	1.628	1.634	1.639	1.645	1.651	1.657	1.662	1.668	1.674	570
580	1.674	1.680	1.685	1.691	1.697	1.703	1.709	1.715	1.720	1.726	1.732	580
590	1.732	1.738	1.744	1.750	1.756	1.762	1.767	1.773	1.779	1.785	1.791	590
600	1.791	1.797	1.803	1.809	1.815	1.821	1.827	1.833	1.839	1.845	1.851	600
610	1.851	1.857	1.863	1.869	1.875	1.882	1.888	1.894	1.900	1.906	1.912	610
620	1.912	1.918	1.924	1.931	1.937	1.943	1.949	1.955	1.961	1.968	1.974	620
630	1.974	1.980	1.986	1.993	1.999	2.005	2.011	2.018	2.024	2.030	2.036	630
640	2.036	2.043	2.049	2.055	2.062	2.068	2.074	2.081	2.087	2.094	2.100	640
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type B Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — **Reference Junctions at 0 C**

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS											
650	2.100	2.104	2.113	2.119	2.126	2.132	2.139	2.145	2.151	2.158	2.164	650
660	2.164	2.171	2.177	2.184	2.190	2.197	2.203	2.210	2.216	2.223	2.230	660
670	2.230	2.236	2.243	2.249	2.256	2.263	2.269	2.276	2.282	2.289	2.296	670
680	2.296	2.302	2.309	2.316	2.322	2.329	2.336	2.343	2.349	2.356	2.363	680
690	2.363	2.369	2.376	2.383	2.390	2.396	2.403	2.410	2.417	2.424	2.430	690
700	2.430	2.437	2.444	2.451	2.458	2.465	2.472	2.478	2.485	2.492	2.499	700
710	2.499	2.506	2.513	2.520	2.527	2.534	2.541	2.548	2.555	2.562	2.569	710
720	2.569	2.576	2.583	2.590	2.597	2.604	2.611	2.618	2.625	2.632	2.639	720
730	2.639	2.646	2.653	2.660	2.667	2.674	2.682	2.689	2.696	2.703	2.710	730
740	2.710	2.717	2.724	2.732	2.739	2.746	2.753	2.760	2.768	2.775	2.782	740
750	2.782	2.789	2.797	2.804	2.811	2.818	2.826	2.833	2.840	2.848	2.855	750
760	2.855	2.862	2.869	2.877	2.884	2.892	2.899	2.906	2.914	2.921	2.928	760
770	2.928	2.936	2.943	2.951	2.958	2.966	2.973	2.980	2.988	2.995	3.003	770
780	3.003	3.010	3.018	3.025	3.033	3.040	3.048	3.055	3.063	3.070	3.078	780
790	3.078	3.086	3.093	3.101	3.108	3.116	3.124	3.131	3.139	3.146	3.154	790
800	3.154	3.162	3.169	3.177	3.185	3.192	3.200	3.208	3.215	3.223	3.231	800
810	3.231	3.239	3.246	3.254	3.262	3.269	3.277	3.285	3.293	3.301	3.308	810
820	3.308	3.316	3.324	3.332	3.340	3.347	3.355	3.363	3.371	3.379	3.387	820
830	3.387	3.395	3.402	3.410	3.418	3.426	3.434	3.442	3.450	3.458	3.466	830
840	3.466	3.474	3.482	3.490	3.498	3.506	3.514	3.522	3.530	3.538	3.546	840
850	3.546	3.554	3.562	3.570	3.578	3.586	3.594	3.602	3.610	3.618	3.626	850
860	3.626	3.634	3.643	3.651	3.659	3.667	3.675	3.683	3.691	3.700	3.708	860
870	3.708	3.716	3.724	3.732	3.741	3.749	3.757	3.765	3.773	3.782	3.790	870
880	3.790	3.798	3.806	3.815	3.823	3.831	3.840	3.848	3.856	3.865	3.873	880
890	3.873	3.881	3.890	3.898	3.906	3.915	3.923	3.931	3.940	3.948	3.957	890
900	3.957	3.965	3.973	3.982	3.990	3.999	4.007	4.016	4.024	4.032	4.041	900
910	4.041	4.049	4.058	4.066	4.075	4.083	4.092	4.100	4.109	4.117	4.126	910
920	4.126	4.135	4.143	4.152	4.160	4.169	4.177	4.186	4.195	4.203	4.212	920
930	4.212	4.220	4.229	4.238	4.246	4.255	4.264	4.272	4.281	4.290	4.298	930
940	4.298	4.307	4.316	4.325	4.333	4.342	4.351	4.359	4.368	4.377	4.386	940
950	4.386	4.394	4.403	4.412	4.421	4.430	4.438	4.447	4.456	4.465	4.474	950
960	4.474	4.483	4.491	4.500	4.509	4.518	4.527	4.536	4.545	4.553	4.562	960
970	4.562	4.571	4.580	4.589	4.598	4.607	4.616	4.625	4.634	4.643	4.652	970
980	4.652	4.661	4.670	4.679	4.688	4.697	4.706	4.715	4.724	4.733	4.742	980
990	4.742	4.751	4.760	4.769	4.778	4.787	4.796	4.805	4.814	4.824	4.833	990
1.000	4.833	4.842	4.851	4.860	4.869	4.878	4.887	4.897	4.906	4.915	4.924	1.000
1.010	4.924	4.933	4.942	4.952	4.961	4.970	4.979	4.988	4.998	5.007	5.016	1.010
1.020	5.016	5.025	5.035	5.044	5.053	5.063	5.072	5.081	5.090	5.100	5.109	1.020
1.030	5.109	5.118	5.128	5.137	5.146	5.156	5.165	5.174	5.184	5.193	5.202	1.030
1.040	5.202	5.212	5.221	5.231	5.240	5.249	5.259	5.268	5.278	5.287	5.297	1.040
1.050	5.297	5.306	5.316	5.325	5.334	5.344	5.353	5.363	5.372	5.382	5.391	1.050
1.060	5.391	5.401	5.410	5.420	5.429	5.439	5.449	5.458	5.468	5.477	5.487	1.060
1.070	5.487	5.496	5.506	5.516	5.525	5.535	5.544	5.554	5.564	5.573	5.583	1.070
1.080	5.583	5.593	5.602	5.612	5.621	5.631	5.641	5.651	5.660	5.670	5.680	1.080
1.090	5.680	5.689	5.699	5.709	5.718	5.728	5.738	5.748	5.757	5.767	5.777	1.090
1.100	5.777	5.787	5.796	5.806	5.816	5.826	5.836	5.845	5.855	5.865	5.875	1.100
1.110	5.875	5.885	5.895	5.904	5.914	5.924	5.934	5.944	5.954	5.964	5.973	1.110
1.120	5.973	5.983	5.993	6.003	6.013	6.023	6.033	6.043	6.053	6.063	6.073	1.120
1.130	6.073	6.083	6.093	6.102	6.112	6.122	6.132	6.142	6.152	6.162	6.172	1.130
1.140	6.172	6.182	6.192	6.202	6.212	6.223	6.233	6.243	6.253	6.263	6.273	1.140
1.150	6.273	6.283	6.293	6.303	6.313	6.323	6.333	6.343	6.353	6.364	6.374	1.150
1.160	6.374	6.384	6.394	6.404	6.414	6.424	6.435	6.445	6.455	6.465	6.475	1.160
1.170	6.475	6.485	6.496	6.506	6.516	6.526	6.536	6.547	6.557	6.567	6.577	1.170
1.180	6.577	6.588	6.598	6.608	6.618	6.629	6.639	6.649	6.659	6.670	6.680	1.180
1.190	6.680	6.690	6.701	6.711	6.721	6.732	6.742	6.752	6.763	6.773	6.783	1.190
1.200	6.783	6.794	6.804	6.814	6.825	6.835	6.846	6.856	6.866	6.877	6.887	1.200
1.210	6.887	6.898	6.908	6.918	6.929	6.939	6.950	6.960	6.971	6.981	6.991	1.210
1.220	6.991	7.002	7.012	7.023	7.033	7.044	7.054	7.065	7.075	7.086	7.096	1.220
1.230	7.096	7.107	7.117	7.128	7.138	7.149	7.159	7.170	7.181	7.191	7.202	1.230
1.240	7.202	7.212	7.223	7.233	7.244	7.255	7.265	7.276	7.286	7.297	7.308	1.240
1.250	7.308	7.318	7.329	7.339	7.350	7.361	7.371	7.382	7.393	7.403	7.414	1.250
1.260	7.414	7.425	7.435	7.446	7.457	7.467	7.478	7.489	7.500	7.510	7.521	1.260
1.270	7.521	7.532	7.542	7.553	7.564	7.575	7.585	7.596	7.607	7.618	7.628	1.270
1.280	7.628	7.639	7.650	7.661	7.671	7.682	7.693	7.704	7.715	7.725	7.736	1.280
1.290	7.736	7.747	7.758	7.769	7.780	7.790	7.801	7.812	7.823	7.834	7.845	1.290
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type B Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — **Reference Junctions at 0 C**

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS											
1.300	7.845	7.855	7.866	7.877	7.888	7.899	7.910	7.921	7.932	7.943	7.953	1.300
1.310	7.953	7.964	7.975	7.986	7.997	8.008	8.019	8.030	8.041	8.052	8.063	1.310
1.320	8.063	8.074	8.085	8.096	8.107	8.118	8.128	8.139	8.150	8.161	8.172	1.320
1.330	8.172	8.183	8.194	8.205	8.216	8.227	8.238	8.249	8.261	8.272	8.283	1.330
1.340	8.283	8.294	8.305	8.316	8.327	8.338	8.349	8.360	8.371	8.382	8.393	1.340
1.350	8.393	8.404	8.415	8.426	8.437	8.449	8.460	8.471	8.482	8.493	8.504	1.350
1.360	8.504	8.515	8.526	8.538	8.549	8.560	8.571	8.582	8.593	8.604	8.616	1.360
1.370	8.616	8.627	8.638	8.649	8.660	8.671	8.683	8.694	8.705	8.716	8.727	1.370
1.380	8.727	8.738	8.750	8.761	8.772	8.783	8.795	8.806	8.817	8.828	8.839	1.380
1.390	8.839	8.851	8.862	8.873	8.884	8.896	8.907	8.918	8.929	8.941	8.952	1.390
1.400	8.952	8.963	8.974	8.986	8.997	9.008	9.020	9.031	9.042	9.053	9.065	1.400
1.410	9.065	9.076	9.087	9.099	9.110	9.121	9.133	9.144	9.155	9.167	9.178	1.410
1.420	9.178	9.189	9.201	9.212	9.223	9.235	9.246	9.257	9.269	9.280	9.291	1.420
1.430	9.291	9.303	9.314	9.326	9.337	9.348	9.360	9.371	9.382	9.394	9.405	1.430
1.440	9.405	9.417	9.428	9.439	9.451	9.462	9.474	9.485	9.497	9.508	9.519	1.440
1.450	9.519	9.531	9.542	9.554	9.565	9.577	9.588	9.599	9.611	9.622	9.634	1.450
1.460	9.634	9.645	9.657	9.668	9.680	9.691	9.703	9.714	9.726	9.737	9.748	1.460
1.470	9.748	9.760	9.771	9.783	9.794	9.806	9.817	9.829	9.840	9.852	9.863	1.470
1.480	9.863	9.875	9.886	9.898	9.909	9.921	9.933	9.944	9.956	9.967	9.979	1.480
1.490	9.979	9.990	10.002	10.013	10.025	10.036	10.048	10.059	10.071	10.082	10.094	1.490
1.500	10.094	10.106	10.117	10.129	10.140	10.152	10.163	10.175	10.187	10.198	10.210	1.500
1.510	10.210	10.221	10.233	10.244	10.256	10.268	10.279	10.291	10.302	10.314	10.325	1.510
1.520	10.325	10.337	10.349	10.360	10.372	10.383	10.395	10.407	10.418	10.430	10.441	1.520
1.530	10.441	10.453	10.465	10.476	10.488	10.500	10.511	10.523	10.534	10.546	10.558	1.530
1.540	10.558	10.569	10.581	10.593	10.604	10.616	10.627	10.639	10.651	10.662	10.674	1.540
1.550	10.674	10.686	10.697	10.709	10.721	10.732	10.744	10.756	10.767	10.779	10.790	1.550
1.560	10.790	10.802	10.814	10.825	10.837	10.849	10.860	10.872	10.884	10.895	10.907	1.560
1.570	10.907	10.919	10.930	10.942	10.954	10.965	10.977	10.989	11.000	11.012	11.024	1.570
1.580	11.024	11.035	11.047	11.059	11.070	11.082	11.094	11.105	11.117	11.129	11.141	1.580
1.590	11.141	11.152	11.164	11.176	11.187	11.199	11.211	11.222	11.234	11.246	11.257	1.590
1.600	11.257	11.269	11.281	11.292	11.304	11.316	11.328	11.339	11.351	11.363	11.374	1.600
1.610	11.374	11.386	11.398	11.409	11.421	11.433	11.444	11.456	11.468	11.480	11.491	1.610
1.620	11.491	11.503	11.515	11.526	11.538	11.550	11.561	11.573	11.585	11.597	11.608	1.620
1.630	11.608	11.620	11.632	11.643	11.655	11.667	11.678	11.690	11.702	11.714	11.725	1.630
1.640	11.725	11.737	11.749	11.760	11.772	11.784	11.795	11.807	11.819	11.830	11.842	1.640
1.650	11.842	11.854	11.866	11.877	11.889	11.901	11.912	11.924	11.936	11.947	11.959	1.650
1.660	11.959	11.971	11.983	11.994	12.006	12.018	12.029	12.041	12.053	12.064	12.076	1.660
1.670	12.076	12.088	12.099	12.111	12.123	12.134	12.146	12.158	12.170	12.181	12.193	1.670
1.680	12.193	12.205	12.216	12.228	12.240	12.251	12.263	12.275	12.286	12.298	12.310	1.680
1.690	12.310	12.321	12.333	12.345	12.356	12.368	12.380	12.391	12.403	12.415	12.426	1.690
1.700	12.426	12.438	12.450	12.461	12.473	12.485	12.496	12.508	12.520	12.531	12.543	1.700
1.710	12.543	12.555	12.566	12.578	12.590	12.601	12.613	12.624	12.636	12.648	12.659	1.710
1.720	12.659	12.671	12.683	12.694	12.706	12.718	12.729	12.741	12.752	12.764	12.776	1.720
1.730	12.776	12.787	12.799	12.811	12.822	12.834	12.845	12.857	12.869	12.880	12.892	1.730
1.740	12.892	12.903	12.915	12.927	12.938	12.950	12.961	12.973	12.985	12.996	13.008	1.740
1.750	13.008	13.019	13.031	13.043	13.054	13.066	13.077	13.089	13.100	13.112	13.124	1.750
1.760	13.124	13.135	13.147	13.158	13.170	13.181	13.193	13.204	13.216	13.228	13.239	1.760
1.770	13.239	13.251	13.262	13.274	13.285	13.297	13.308	13.320	13.331	13.343	13.354	1.770
1.780	13.354	13.366	13.378	13.389	13.401	13.412	13.424	13.435	13.447	13.458	13.470	1.780
1.790	13.470	13.481	13.493	13.504	13.516	13.527	13.539	13.550	13.562	13.573	13.585	1.790
1.800	13.585	13.596	13.607	13.619	13.630	13.642	13.653	13.665	13.676	13.688	13.699	1.800
1.810	13.699	13.711	13.722	13.733	13.745	13.756	13.768	13.779	13.791	13.802	13.814	1.810
1.820	13.814											1.820
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type K Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
350	14.292	14.334	14.376	14.418	14.460	14.502	14.544	14.586	14.628	14.670	14.712	350
360	14.712	14.754	14.796	14.838	14.880	14.922	14.964	15.006	15.048	15.090	15.132	360
370	15.132	15.174	15.216	15.258	15.300	15.342	15.384	15.426	15.468	15.510	15.552	370
380	15.552	15.594	15.636	15.679	15.721	15.763	15.805	15.847	15.889	15.931	15.974	380
390	15.974	16.016	16.058	16.100	16.142	16.184	16.227	16.269	16.311	16.353	16.395	390
400	16.395	16.438	16.480	16.522	16.564	16.607	16.649	16.691	16.733	16.776	16.818	400
410	16.818	16.860	16.902	16.945	16.987	17.029	17.072	17.114	17.156	17.199	17.241	410
420	17.241	17.283	17.326	17.368	17.410	17.453	17.495	17.537	17.580	17.622	17.664	420
430	17.664	17.707	17.749	17.792	17.834	17.876	17.919	17.961	18.004	18.046	18.088	430
440	18.088	18.131	18.173	18.216	18.258	18.301	18.343	18.385	18.428	18.470	18.513	440
450	18.513	18.555	18.598	18.640	18.683	18.725	18.768	18.810	18.853	18.895	18.938	450
460	18.938	18.980	19.023	19.065	19.108	19.150	19.193	19.235	19.278	19.320	19.363	460
470	19.363	19.405	19.448	19.490	19.533	19.576	19.618	19.661	19.703	19.746	19.788	470
480	19.788	19.831	19.873	19.916	19.959	20.001	20.044	20.086	20.129	20.172	20.214	480
490	20.214	20.257	20.299	20.342	20.385	20.427	20.470	20.512	20.555	20.598	20.640	490
500	20.640	20.683	20.725	20.768	20.811	20.853	20.896	20.938	20.981	21.024	21.066	500
510	21.066	21.109	21.152	21.194	21.237	21.280	21.322	21.365	21.407	21.450	21.493	510
520	21.493	21.535	21.578	21.621	21.663	21.706	21.749	21.791	21.834	21.876	21.919	520
530	21.919	21.962	22.004	22.047	22.090	22.132	22.175	22.218	22.260	22.303	22.346	530
540	22.346	22.388	22.431	22.473	22.516	22.559	22.601	22.644	22.687	22.729	22.772	540
550	22.772	22.815	22.857	22.900	22.942	22.985	23.028	23.070	23.113	23.156	23.198	550
560	23.198	23.241	23.284	23.326	23.369	23.411	23.454	23.497	23.539	23.582	23.624	560
570	23.624	23.667	23.710	23.752	23.795	23.837	23.880	23.923	23.965	24.008	24.050	570
580	24.050	24.093	24.136	24.178	24.221	24.263	24.306	24.348	24.391	24.434	24.476	580
590	24.476	24.519	24.561	24.604	24.646	24.689	24.731	24.774	24.817	24.859	24.902	590
600	24.902	24.944	24.987	25.029	25.072	25.114	25.157	25.199	25.242	25.284	25.327	600
610	25.327	25.369	25.412	25.454	25.497	25.539	25.582	25.624	25.666	25.709	25.751	610
620	25.751	25.794	25.836	25.879	25.921	25.964	26.006	26.048	26.091	26.133	26.176	620
630	26.176	26.218	26.260	26.303	26.345	26.387	26.430	26.472	26.515	26.557	26.599	630
640	26.599	26.642	26.684	26.726	26.769	26.811	26.853	26.896	26.938	26.980	27.022	640
650	27.022	27.065	27.107	27.149	27.192	27.234	27.276	27.318	27.361	27.403	27.445	650
660	27.445	27.487	27.529	27.572	27.614	27.656	27.698	27.740	27.783	27.825	27.867	660
670	27.867	27.909	27.951	27.993	28.035	28.078	28.120	28.162	28.204	28.246	28.288	670
680	28.288	28.330	28.372	28.414	28.456	28.498	28.540	28.583	28.625	28.667	28.709	680
690	28.709	28.751	28.793	28.835	28.877	28.919	28.961	29.002	29.044	29.086	29.128	690
700	29.128	29.170	29.212	29.254	29.296	29.338	29.380	29.422	29.464	29.505	29.547	700
710	29.547	29.589	29.631	29.673	29.715	29.756	29.798	29.840	29.882	29.924	29.965	710
720	29.965	30.007	30.049	30.091	30.132	30.174	30.216	30.257	30.299	30.341	30.383	720
730	30.383	30.424	30.466	30.508	30.549	30.591	30.632	30.674	30.716	30.757	30.799	730
740	30.799.	30.840	30.882	30.924	30.965	31.007	31.048	31.090	31.131	31.173	31.214	740
750	31.214	31.256	31.297	31.339	31.380	31.422	31.463	31.504	31.546	31.587	31.629	750
760	31.629	31.670	31.712	31.753	31.794	31.836	31.877	31.918	31.960	32.001	32.042	760
770	32.042	32.084	32.125	32.166	32.207	32.249	32.290	32.331	32.372	32.414	32.455	770
780	32.455	32.496	32.537	32.578	32.619	32.661	32.702	32.743	32.784	32.825	32.866	780
790	32.866	32.907	32.948	32.990	33.031	33.072	33.113	33.154	33.195	33.236	33.277	790
800	33.277	33.318	33.359	33.400	33.441	33.482	33.523	33.564	33.604	33.645	33.686	800
810	33.686	33.727	33.768	33.809	33.850	33.891	33.931	33.972	34.013	34.054	34.095	810
820	34.095	34.136	34.176	34.217	34.258	34.299	34.339	34.380	34.421	34.461	34.502	820
830	34.502	34.543	34.583	34.624	34.665	34.705	34.746	34.787	34.827	34.868	34.909	830
840	34.909	34.949	34.990	35.030	35.071	35.111	35.152	35.192	35.233	35.273	35.314	840
850	35.314	35.354	35.395	35.435	35.476	35.516	35.557	35.597	35.637	35.678	35.718	850
860	35.718	35.758	35.799	35.839	35.880	35.920	35.960	36.000	36.041	36.081	36.121	860
870	36.121	36.162	36.202	36.242	36.282	36.323	36.363	36.403	36.443	36.483	36.524	870
880	36.524	36.564	36.604	36.644	36.684	36.724	36.764	36.804	36.844	36.885	36.925	880
890	36.925	36.965	37.005	37.045	37.085	37.125	37.165	37.205	37.245	37.285	37.325	890
900	37.325	37.365	37.405	37.445	37.484	37.524	37.564	37.604	37.644	37.684	37.724	900
910	37.724	37.764	37.803	37.843	37.883	37.923	37.963	38.002	38.042	38.082	38.122	910
920	38.122	38.162	38.201	38.241	38.281	38.320	38.360	38.400	38.439	38.479	38.519	920
930	38.519	38.558	38.598	38.638	38.677	38.717	38.756	38.796	38.836	38.875	38.915	930
940	38.915	38.954	38.994	39.033	39.073	39.112	39.152	39.191	39.231	39.270	39.310	940
950	39.310	39.349	39.388	39.428	39.467	39.507	39.546	39.585	39.625	39.664	39.703	950
960	39.703	39.743	39.782	39.821	39.861	39.900	39.939	39.979	40.018	40.057	40.096	960
970	40.096	40.136	40.175	40.214	40.253	40.292	40.332	40.371	40.410	40.449	40.488	970
980	40.488	40.527	40.566	40.605	40.645	40.684	40.723	40.762	40.801	40.840	40.879	980
990	40.879	40.918	40.957	40.996	41.035	41.074	41.113	41.152	41.191	41.230	41.269	990
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type K Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
1.000	41.269	41.308	41.347	41.385	41.424	41.463	41.502	41.541	41.580	41.619	41.657	1.000
1.010	41.657	41.696	41.735	41.774	41.813	41.851	41.890	41.929	41.968	42.006	42.045	1.010
1.020	42.045	42.084	42.123	42.161	42.200	42.239	42.277	42.316	42.355	42.393	42.432	1.020
1.030	42.432	42.470	42.509	42.548	42.586	42.625	42.663	42.702	42.740	42.779	42.817	1.030
1.040	42.817	42.856	42.894	42.933	42.971	43.010	43.048	43.087	43.125	43.164	43.202	1.040
1.050	43.202	43.240	43.279	43.317	43.356	43.394	43.432	43.471	43.509	43.547	43.585	1.050
1.060	43.585	43.624	43.662	43.700	43.739	43.777	43.815	43.853	43.891	43.930	43.968	1.060
1.070	43.968	44.006	44.044	44.082	44.121	44.159	44.197	44.235	44.273	44.311	44.349	1.070
1.080	44.349	44.387	44.425	44.463	44.501	44.539	44.577	44.615	44.653	44.691	44.729	1.080
1.090	44.729	44.767	44.805	44.843	44.881	44.919	44.957	44.995	45.033	45.070	45.108	1.090
1.100	45.108	45.146	45.184	45.222	45.260	45.297	45.335	45.373	45.411	45.448	45.486	1.100
1.110	45.486	45.524	45.561	45.599	45.637	45.675	45.712	45.750	45.787	45.825	45.863	1.110
1.120	45.863	45.900	45.938	45.975	46.013	46.051	46.088	46.126	46.163	46.201	46.238	1.120
1.130	46.238	46.275	46.313	46.350	46.388	46.425	46.463	46.500	46.537	46.575	46.612	1.130
1.140	46.612	46.649	46.687	46.724	46.761	46.799	46.836	46.873	46.910	46.948	46.985	1.140
1.150	46.985	47.022	47.059	47.096	47.134	47.171	47.208	47.245	47.282	47.319	47.356	1.150
1.160	47.356	47.393	47.430	47.468	47.505	47.542	47.579	47.616	47.653	47.689	47.726	1.160
1.170	47.726	47.763	47.800	47.837	47.874	47.911	47.948	47.985	48.021	48.058	48.095	1.170
1.180	48.095	48.132	48.169	48.205	48.242	48.279	48.316	48.352	48.389	48.426	48.462	1.180
1.190	48.462	48.499	48.536	48.572	48.609	48.645	48.682	48.718	48.755	48.792	48.828	1.190
1.200	48.828	48.865	48.901	48.937	48.974	49.010	49.047	49.083	49.120	49.156	49.192	1.200
1.210	49.192	49.229	49.265	49.301	49.338	49.374	49.410	49.446	49.483	49.519	49.555	1.210
1.220	49.555	49.591	49.627	49.663	49.700	49.736	49.772	49.808	49.844	49.880	49.916	1.220
1.230	49.916	49.952	49.988	50.024	50.060	50.096	50.132	50.168	50.204	50.240	50.276	1.230
1.240	50.276	50.311	50.347	50.383	50.419	50.455	50.491	50.526	50.562	50.598	50.633	1.240
1.250	50.633	50.669	50.705	50.741	50.776	50.812	50.847	50.883	50.919	50.954	50.990	1.250
1.260	50.990	51.025	51.061	51.096	51.132	51.167	51.203	51.238	51.274	51.309	51.344	1.260
1.270	51.344	51.380	51.415	51.450	51.486	51.521	51.556	51.592	51.627	51.662	51.697	1.270
1.280	51.697	51.733	51.768	51.803	51.838	51.873	51.908	51.943	51.979	52.014	52.049	1.280
1.290	52.049	52.084	52.119	52.154	52.189	52.224	52.259	52.294	52.329	52.364	52.398	1.290
1.300	52.398	52.433	52.468	52.503	52.538	52.573	52.608	52.642	52.677	52.712	52.747	1.300
1.310	52.747	52.781	52.816	52.851	52.886	52.920	52.955	52.989	53.024	53.059	53.093	1.310
1.320	53.093	53.128	53.162	53.197	53.232	53.266	53.301	53.335	53.370	53.404	53.439	1.320
1.330	53.439	53.473	53.507	53.542	53.576	53.611	53.645	53.679	53.714	53.748	53.782	1.330
1.340	53.782	53.817	53.851	53.885	53.920	53.954	53.988	54.022	54.057	54.091	54.125	1.340
1.350	54.125	54.159	54.193	54.228	54.262	54.296	54.330	54.364	54.398	54.432	54.466	1.350
1.360	54.466	54.501	54.535	54.569	54.603	54.637	54.671	54.705	54.739	54.773	54.807	1.360
1.370	54.807	54.841	54.875									1.370
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type J Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
					THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS							
1.000	57.942	58.001	58.060	58.120	58.179	58.238	58.297	58.356	58.415	58.474	58.533	1.000
1.010	58.533	58.592	58.651	58.710	58.769	58.827	58.886	58.945	59.004	59.063	59.121	1.010
1.020	59.121	59.180	59.239	59.298	59.356	59.415	59.474	59.532	59.591	59.650	59.708	1.020
1.030	59.708	59.767	59.825	59.884	59.942	60.001	60.059	60.118	60.176	60.235	60.293	1.030
1.040	60.293	60.351	60.410	60.468	60.527	60.585	60.643	60.702	60.760	60.818	60.876	1.040
1.050	60.876	60.935	60.993	61.051	61.109	61.168	61.226	61.284	61.342	61.400	61.459	1.050
1.060	61.459	61.517	61.575	61.633	61.691	61.749	61.807	61.865	61.923	61.981	62.039	1.060
1.070	62.039	62.097	62.156	62.214	62.272	62.330	62.388	62.446	62.504	62.562	62.619	1.070
1.080	62.619	62.677	62.735	62.793	62.851	62.909	62.967	63.025	63.083	63.141	63.199	1.080
1.090	63.199	63.257	63.314	63.372	63.430	63.488	63.546	63.604	63.662	63.719	63.777	1.090
1.100	63.777	63.835	63.893	63.951	64.009	64.066	64.124	64.182	64.240	64.298	64.355	1.100
1.110	64.355	64.413	64.471	64.529	64.586	64.644	64.702	64.760	64.817	64.875	64.933	1.110
1.120	64.933	64.991	65.048	65.106	65.164	65.222	65.279	65.337	65.395	65.453	65.510	1.120
1.130	65.510	65.568	65.626	65.683	65.741	65.799	65.856	65.914	65.972	66.029	66.087	1.130
1.140	66.087	66.145	66.202	66.260	66.318	66.375	66.433	66.491	66.548	66.606	66.664	1.140
1.150	66.664	66.721	66.779	66.836	66.894	66.952	67.009	67.067	67.124	67.182	67.240	1.150
1.160	67.240	67.297	67.355	67.412	67.470	67.527	67.585	67.643	67.700	67.758	67.815	1.160
1.170	67.815	67.873	67.930	67.988	68.045	68.103	68.160	68.217	68.275	68.332	68.390	1.170
1.180	68.390	68.447	68.505	68.562	68.619	68.677	68.734	68.792	68.849	68.906	68.964	1.180
1.190	68.964	69.021	69.078	69.135	69.193	69.250	69.307	69.364	69.422	69.479	69.536	1.190
1.200	69.536											1.200
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type K Thermocouples. Nickel-Chromium/Nickel-Aluminium

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
					THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS							
-270	-6.458											-270
-260	-6.441	-6.444	-6.446	-6.448	-6.450	-6.452	-6.453	-6.455	-6.456	-6.457	-6.458	-260
-250	-6.404	-6.408	-6.413	-6.417	-6.421	-6.425	-6.429	-6.432	-6.435	-6.438	-6.441	-250
-240	-6.344	-6.351	-6.358	-6.364	-6.371	-6.377	-6.382	-6.388	-6.394	-6.399	-6.404	-240
-230	-6.262	-6.271	-6.280	-6.289	-6.297	-6.306	-6.314	-6.322	-6.329	-6.337	-6.344	-230
-220	-6.158	-6.170	-6.181	-6.192	-6.202	-6.213	-6.223	-6.233	-6.243	-6.253	-6.262	-220
-210	-6.035	-6.048	-6.061	-6.074	-6.087	-6.099	-6.111	-6.123	-6.135	-6.147	-6.158	-210
-200	-5.891	-5.907	-5.922	-5.936	-5.951	-5.965	-5.980	-5.994	-6.007	-6.021	-6.035	-200
-190	-5.730	-5.747	-5.763	-5.780	-5.796	-5.813	-5.829	-5.845	-5.860	-5.876	-5.891	-190
-180	-5.550	-5.569	-5.587	-5.606	-5.624	-5.642	-5.660	-5.678	-5.695	-5.712	-5.730	-180
-170	-5.354	-5.374	-5.394	-5.414	-5.434	-5.454	-5.474	-5.493	-5.512	-5.531	-5.550	-170
-160	-5.141	-5.163	-5.185	-5.207	-5.228	-5.249	-5.271	-5.292	-5.313	-5.333	-5.354	-160
-150	-4.912	-4.936	-4.959	-4.983	-5.006	-5.029	-5.051	-5.074	-5.097	-5.119	-5.141	-150
-140	-4.669	-4.694	-4.719	-4.743	-4.768	-4.792	-4.817	-4.841	-4.865	-4.889	-4.912	-140
-130	-4.410	-4.437	-4.463	-4.489	-4.515	-4.541	-4.567	-4.593	-4.618	-4.644	-4.669	-130
-120	-4.138	-4.166	-4.193	-4.221	-4.248	-4.276	-4.303	-4.330	-4.357	-4.384	-4.410	-120
-110	-3.852	-3.881	-3.910	-3.939	-3.968	-3.997	-4.025	-4.053	-4.082	-4.110	-4.138	-110
-100	-3.553	-3.584	-3.614	-3.644	-3.674	-3.704	-3.734	-3.764	-3.793	-3.823	-3.852	-100
-90	-3.242	-3.274	-3.305	-3.337	-3.368	-3.399	-3.430	-3.461	-3.492	-3.523	-3.553	-90
-80	-2.920	-2.953	-2.985	-3.018	-3.050	-3.082	-3.115	-3.147	-3.179	-3.211	-3.242	-80
-70	-2.586	-2.620	-2.654	-2.687	-2.721	-2.754	-2.788	-2.821	-2.854	-2.887	-2.920	-70
-60	-2.243	-2.277	-2.312	-2.347	-2.381	-2.416	-2.450	-2.484	-2.518	-2.552	-2.586	-60
-50	-1.889	-1.925	-1.961	-1.996	-2.032	-2.067	-2.102	-2.137	-2.173	-2.208	-2.243	-50
-40	-1.527	-1.563	-1.600	-1.636	-1.673	-1.709	-1.745	-1.781	-1.817	-1.853	-1.889	-40
-30	-1.156	-1.193	-1.231	-1.268	-1.305	-1.342	-1.379	-1.416	-1.453	-1.490	-1.527	-30
-20	-0.777	-0.816	-0.854	-0.892	-0.930	-0.968	-1.005	-1.043	-1.081	-1.118	-1.156	-20
-10	-0.392	-0.431	-0.469	-0.508	-0.547	-0.585	-0.624	-0.662	-0.701	-0.739	-0.777	-10
- 0	0.000	-0.039	-0.079	-0.118	-0.157	-0.197	-0.236	-0.275	-0.314	-0.353	-0.392	- 0
0	0.000	0.039	0.079	0.119	0.158	0.198	0.238	0.277	0.317	0.357	0.397	0
10	0.397	0.437	0.477	0.517	0.557	0.597	0.637	0.677	0.718	0.758	0.798	10
20	0.798	0.838	0.879	0.919	0.960	1.000	1.041	1.081	1.122	1.162	1.203	20
30	1.203	1.244	1.285	1.325	1.366	1.407	1.448	1.489	1.529	1.570	1.611	30
40	1.611	1.652	1.693	1.734	1.776	1.817	1.858	1.899	1.940	1.981	2.022	40
50	2.022	2.064	2.105	2.146	2.188	2.229	2.270	2.312	2.353	2.394	2.436	50
60	2.436	2.477	2.519	2.560	2.601	2.643	2.684	2.726	2.767	2.809	2.850	60
70	2.850	2.892	2.933	2.975	3.016	3.058	3.100	3.141	3.183	3.224	3.266	70
80	3.266	3.307	3.349	3.390	3.432	3.473	3.515	3.556	3.598	3.639	3.681	80
90	3.681	3.722	3.764	3.805	3.847	3.888	3.930	3.971	4.012	4.054	4.095	90
100	4.095	4.137	4.178	4.219	4.261	4.302	4.343	4.384	4.426	4.467	4.508	100
110	4.508	4.549	4.590	4.632	4.673	4.714	4.755	4.796	4.837	4.878	4.919	110
120	4.919	4.960	5.001	5.042	5.083	5.124	5.164	5.205	5.246	5.287	5.327	120
130	5.327	5.368	5.409	5.450	5.490	5.531	5.571	5.612	5.652	5.693	5.733	130
140	5.733	5.774	5.814	5.855	5.895	5.936	5.976	6.016	6.057	6.097	6.137	140
150	6.137	6.177	6.218	6.258	6.298	6.338	6.378	6.419	6.459	6.499	6.539	150
160	6.539	6.579	6.619	6.659	6.699	6.739	6.779	6.819	6.859	6.899	6.939	160
170	6.939	6.979	7.019	7.059	7.099	7.139	7.179	7.219	7.259	7.299	7.338	170
180	7.338	7.378	7.418	7.458	7.498	7.538	7.578	7.618	7.658	7.697	7.737	180
190	7.737	7.777	7.817	7.857	7.8[illegible]	7.937	7.977	8.017	8.057	8.097	8.137	190
200	8.137	8.177	8.216	8.256	8.296	8.336	8.376	8.416	8.456	8.497	8.537	200
210	8.537	8.577	8.617	8.657	8.697	8.737	8.777	8.817	8.857	8.898	8.938	210
220	8.938	8.978	9.018	9.058	9.099	9.139	9.179	9.220	9.260	9.300	9.341	220
230	9.341	9.381	9.421	9.462	9.502	9.543	9.583	9.624	9.664	9.705	9.745	230
240	9.745	9.786	9.826	9.867	9.907	9.948	9.989	10.029	10.070	10.111	10.151	240
250	10.151	10.192	10.233	10.274	10.315	10.355	10.396	10.437	10.478	10.519	10.560	250
260	10.560	10.600	10.641	10.682	10.723	10.764	10.805	10.846	10.887	10.928	10.969	260
270	10.969	11.010	11.051	11.093	11.134	11.175	11.216	11.257	11.298	11.339	11.381	270
280	11.381	11.422	11.463	11.504	11.546	11.587	11.628	11.669	11.711	11.752	11.793	280
290	11.793	11.835	11.876	11.918	11.959	12.000	12.042	12.083	12.125	12.166	12.207	290
300	12.207	12.249	12.290	12.332	12.373	12.415	12.456	12.498	12.539	12.581	12.623	300
310	12.623	12.664	12.706	12.747	12.789	12.831	12.872	12.914	12.955	12.997	13.039	310
320	13.039	13.080	13.122	13.164	13.205	13.247	13.289	13.331	13.372	13.414	13.456	320
330	13.456	13.497	13.539	13.581	13.623	13.665	13.706	13.748	13.790	13.832	13.874	330
340	13.874	13.915	13.957	13.999	14.041	14.083	14.125	14.167	14.208	14.250	14.292	340
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type S Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
600	5.237	5.247	5.258	5.268	5.278	5.288	5.298	5.309	5.319	5.329	5.339	600
610	5.339	5.350	5.360	5.370	5.380	5.391	5.401	5.411	5.421	5.431	5.442	610
620	5.442	5.452	5.462	5.473	5.483	5.493	5.503	5.514	5.524	5.534	5.544	620
630	5.544	5.555	5.565	5.575	5.586	5.596	5.606	5.617	5.627	5.637	5.648	630
640	5.648	5.658	5.668	5.679	5.689	5.700	5.710	5.720	5.731	5.741	5.751	640
650	5.751	5.762	5.772	5.782	5.793	5.803	5.814	5.824	5.834	5.845	5.855	650
660	5.855	5.866	5.876	5.887	5.897	5.907	5.918	5.928	5.939	5.949	5.960	660
670	5.960	5.970	5.980	5.991	6.001	6.012	6.022	6.033	6.043	6.054	6.064	670
680	6.064	6.075	6.085	6.096	6.106	6.117	6.127	6.138	6.148	6.159	6.169	680
690	6.169	6.180	6.190	6.201	6.211	6.222	6.232	6.243	6.253	6.264	6.274	690
700	6.274	6.285	6.295	6.306	6.316	6.327	6.338	6.348	6.359	6.369	6.380	700
710	6.380	6.390	6.401	6.412	6.422	6.433	6.443	6.454	6.465	6.475	6.486	710
720	6.486	6.496	6.507	6.518	6.528	6.539	6.549	6.560	6.571	6.581	6.592	720
730	6.592	6.603	6.613	6.624	6.635	6.645	6.656	6.667	6.677	6.688	6.699	730
740	6.699	6.709	6.720	6.731	6.741	6.752	6.763	6.773	6.784	6.795	6.805	740
750	6.805	6.816	6.827	6.838	6.848	6.859	6.870	6.880	6.891	6.902	6.913	750
760	6.913	6.923	6.934	6.945	6.956	6.966	6.977	6.988	6.999	7.009	7.020	760
770	7.020	7.031	7.042	7.053	7.063	7.074	7.085	7.096	7.107	7.117	7.128	770
780	7.128	7.139	7.150	7.161	7.171	7.182	7.193	7.204	7.215	7.225	7.236	780
790	7.236	7.247	7.258	7.269	7.280	7.291	7.301	7.312	7.323	7.334	7.345	790
800	7.345	7.356	7.367	7.377	7.388	7.399	7.410	7.421	7.432	7.443	7.454	800
810	7.454	7.465	7.476	7.486	7.497	7.508	7.519	7.530	7.541	7.552	7.563	810
820	7.563	7.574	7.585	7.596	7.607	7.618	7.629	7.640	7.651	7.661	7.672	820
830	7.672	7.683	7.694	7.705	7.716	7.727	7.738	7.749	7.760	7.771	7.782	830
840	7.782	7.793	7.804	7.815	7.826	7.837	7.848	7.859	7.870	7.881	7.892	840
850	7.892	7.904	7.915	7.926	7.937	7.948	7.959	7.970	7.981	7.992	8.003	850
860	8.003	8.014	8.025	8.036	8.047	8.058	8.069	8.081	8.092	8.103	8.114	860
870	8.114	8.125	8.136	8.147	8.158	8.169	8.180	8.192	8.203	8.214	8.225	870
880	8.225	8.236	8.247	8.258	8.270	8.281	8.292	8.303	8.314	8.325	8.336	880
890	8.336	8.348	8.359	8.370	8.381	8.392	8.404	8.415	8.426	8.437	8.448	890
900	8.448	8.460	8.471	8.482	8.493	8.504	8.516	8.527	8.538	8.549	8.560	900
910	8.560	8.572	8.583	8.594	8.605	8.617	8.628	8.639	8.650	8.662	8.673	910
920	8.673	8.684	8.695	8.707	8.718	8.729	8.741	8.752	8.763	8.774	8.786	920
930	8.786	8.797	8.808	8.820	8.831	8.842	8.854	8.865	8.876	8.888	8.899	930
940	8.899	8.910	8.922	8.933	8.944	8.956	8.967	8.978	8.990	9.001	9.012	940
950	9.012	9.024	9.035	9.047	9.058	9.069	9.081	9.092	9.103	9.115	9.126	950
960	9.126	9.138	9.149	9.160	9.172	9.183	9.195	9.206	9.217	9.229	9.240	960
970	9.240	9.252	9.263	9.275	9.286	9.298	9.309	9.320	9.332	9.343	9.355	970
980	9.355	9.366	9.378	9.389	9.401	9.412	9.424	9.435	9.447	9.458	9.470	980
990	9.470	9.481	9.493	9.504	9.516	9.527	9.539	9.550	9.562	9.573	9.585	990
1,000	9.585	9.596	9.608	9.619	9.631	9.642	9.654	9.665	9.677	9.689	9.700	1,000
1,010	9.700	9.712	9.723	9.735	9.746	9.758	9.770	9.781	9.793	9.804	9.816	1,010
1,020	9.816	9.828	9.839	9.851	9.862	9.874	9.886	9.897	9.909	9.920	9.932	1,020
1,030	9.932	9.944	9.955	9.967	9.979	9.990	10.002	10.013	10.025	10.037	10.048	1,030
1,040	10.048	10.060	10.072	10.083	10.095	10.107	10.118	10.130	10.142	10.154	10.165	1,040
1,050	10.165	10.177	10.189	10.200	10.212	10.224	10.235	10.247	10.259	10.271	10.282	1,050
1,060	10.282	10.294	10.306	10.318	10.329	10.341	10.353	10.364	10.376	10.388	10.400	1,060
1,070	10.400	10.411	10.423	10.435	10.447	10.459	10.470	10.482	10.494	10.506	10.517	1,070
1,080	10.517	10.529	10.541	10.553	10.565	10.576	10.588	10.600	10.612	10.624	10.635	1,080
1,090	10.635	10.647	10.659	10.671	10.683	10.694	10.706	10.718	10.730	10.742	10.754	1,090
1,100	10.754	10.765	10.777	10.789	10.801	10.813	10.825	10.836	10.848	10.860	10.872	1,100
1,110	10.872	10.884	10.896	10.908	10.919	10.931	10.943	10.955	10.967	10.979	10.991	1,110
1,120	10.991	11.003	11.014	11.026	11.038	11.050	11.062	11.074	11.086	11.098	11.110	1,120
1,130	11.110	11.121	11.133	11.145	11.157	11.169	11.181	11.193	11.205	11.217	11.229	1,130
1,140	11.229	11.241	11.252	11.264	11.276	11.288	11.300	11.312	11.324	11.336	11.348	1,140
1,150	11.348	11.360	11.372	11.384	11.396	11.408	11.420	11.432	11.443	11.455	11.467	1,150
1,160	11.467	11.479	11.491	11.503	11.515	11.527	11.539	11.551	11.563	11.575	11.587	1,160
1,170	11.587	11.599	11.611	11.623	11.635	11.647	11.659	11.671	11.683	11.695	11.707	1,170
1,180	11.707	11.719	11.731	11.743	11.755	11.767	11.779	11.791	11.803	11.815	11.827	1,180
1,190	11.827	11.839	11.851	11.863	11.875	11.887	11.899	11.911	11.923	11.935	11.947	1,190
1,200	11.947	11.959	11.971	11.983	11.995	12.007	12.019	12.031	12.043	12.055	12.067	1,200
1,210	12.067	12.079	12.091	12.103	12.116	12.128	12.140	12.152	12.164	12.176	12.188	1,210
1,220	12.188	12.200	12.212	12.224	12.236	12.248	12.260	12.272	12.284	12.296	12.308	1,220
1,230	12.308	12.320	12.332	12.345	12.357	12.369	12.381	12.393	12.405	12.417	12.429	1,230
1,240	12.429	12.441	12.453	12.465	12.477	12.489	12.501	12.514	12.526	12.538	12.550	1,240
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type S Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
1,250	12.550	12.562	12.574	12.586	12.598	12.610	12.622	12.634	12.647	12.659	12.671	1,250
1,260	12.671	12.683	12.695	12.707	12.719	12.731	12.743	12.755	12.767	12.780	12.792	1,260
1,270	12.792	12.804	12.816	12.828	12.840	12.852	12.864	12.876	12.888	12.901	12.913	1,270
1,280	12.913	12.925	12.937	12.949	12.961	12.973	12.985	12.997	13.010	13.022	13.034	1,280
1,290	13.034	13.046	13.058	13.070	13.082	13.094	13.107	13.119	13.131	13.143	13.155	1,290
1,300	13.155	13.167	13.179	13.191	13.203	13.216	13.228	13.240	13.252	13.264	13.276	1,300
1,310	13.276	13.288	13.300	13.313	13.325	13.337	13.349	13.361	13.373	13.385	13.397	1,310
1,320	13.397	13.410	13.422	13.434	13.446	13.458	13.470	13.482	13.495	13.507	13.519	1,320
1,330	13.519	13.531	13.543	13.555	13.567	13.579	13.592	13.604	13.616	13.628	13.640	1,330
1,340	13.640	13.652	13.664	13.677	13.689	13.701	13.713	13.725	13.737	13.749	13.761	1,340
1,350	13.761	13.774	13.786	13.798	13.810	13.822	13.834	13.846	13.859	13.871	13.883	1,350
1,360	13.883	13.895	13.907	13.919	13.931	13.943	13.956	13.968	13.980	13.992	14.004	1,360
1,370	14.004	14.016	14.028	14.040	14.053	14.065	14.077	14.089	14.101	14.113	14.125	1,370
1,380	14.125	14.138	14.150	14.162	14.174	14.186	14.198	14.210	14.222	14.235	14.247	1,380
1,390	14.247	14.259	14.271	14.283	14.295	14.307	14.319	14.332	14.344	14.356	14.368	1,390
1,400	14.368	14.380	14.392	14.404	14.416	14.429	14.441	14.453	14.465	14.477	14.489	1,400
1,410	14.489	14.501	14.513	14.526	14.538	14.550	14.562	14.574	14.586	14.598	14.610	1,410
1,420	14.610	14.622	14.635	14.647	14.659	14.671	14.683	14.695	14.707	14.719	14.731	1,420
1,430	14.731	14.744	14.756	14.768	14.780	14.792	14.804	14.816	14.828	14.840	14.852	1,430
1,440	14.852	14.865	14.877	14.889	14.901	14.913	14.925	14.937	14.949	14.961	14.973	1,440
1,450	14.973	14.985	14.998	15.010	15.022	15.034	15.046	15.058	15.070	15.082	15.094	1,450
1,460	15.094	15.106	15.118	15.130	15.143	15.155	15.167	15.179	15.191	15.203	15.215	1,460
1,470	15.215	15.227	15.239	15.251	15.263	15.275	15.287	15.299	15.311	15.324	15.336	1,470
1,480	15.336	15.348	15.360	15.372	15.384	15.396	15.408	15.420	15.432	15.444	15.456	1,480
1,490	15.456	15.468	15.480	15.492	15.504	15.516	15.528	15.540	15.552	15.564	15.576	1,490
1,500	15.576	15.589	15.601	15.613	15.625	15.637	15.649	15.661	15.673	15.685	15.697	1,500
1,510	15.697	15.709	15.721	15.733	15.745	15.757	15.769	15.781	15.793	15.805	15.817	1,510
1,520	15.817	15.829	15.841	15.853	15.865	15.877	15.889	15.901	15.913	15.925	15.937	1,520
1,530	15.937	15.949	15.961	15.973	15.985	15.997	16.009	16.021	16.033	16.045	16.057	1,530
1,540	16.057	16.069	16.080	16.092	16.104	16.116	16.128	16.140	16.152	16.164	16.176	1,540
1,550	16.176	16.188	16.200	16.212	16.224	16.236	16.248	16.260	16.272	16.284	16.296	1,550
1,560	16.296	16.308	16.319	16.331	16.343	16.355	16.367	16.379	16.391	16.403	16.415	1,560
1,570	16.415	16.427	16.439	16.451	16.462	16.474	16.486	16.498	16.510	16.522	16.534	1,570
1,580	16.534	16.546	16.558	16.569	16.581	16.593	16.605	16.617	16.629	16.641	16.653	1,580
1,590	16.653	16.664	16.676	16.688	16.700	16.712	16.724	16.736	16.747	16.759	16.771	1,590
1,600	16.771	16.783	16.795	16.807	16.819	16.830	16.842	16.854	16.866	16.878	16.890	1,600
1,610	16.890	16.901	16.913	16.925	16.937	16.949	16.960	16.972	16.984	16.996	17.008	1,610
1,620	17.008	17.019	17.031	17.043	17.055	17.067	17.078	17.090	17.102	17.114	17.125	1,620
1,630	17.125	17.137	17.149	17.161	17.173	17.184	17.196	17.208	17.220	17.231	17.243	1,630
1,640	17.243	17.255	17.267	17.278	17.290	17.302	17.313	17.325	17.337	17.349	17.360	1,640
1,650	17.360	17.372	17.384	17.396	17.407	17.419	17.431	17.442	17.454	17.466	17.477	1,650
1,660	17.477	17.489	17.501	17.512	17.524	17.536	17.548	17.559	17.571	17.583	17.594	1,660
1,670	17.594	17.606	17.617	17.629	17.641	17.652	17.664	17.676	17.687	17.699	17.711	1,670
1,680	17.711	17.722	17.734	17.745	17.757	17.769	17.780	17.792	17.803	17.815	17.826	1,680
1,690	17.826	17.838	17.850	17.861	17.873	17.884	17.896	17.907	17.919	17.930	17.942	1,690
1,700	17.942	17.953	17.965	17.976	17.988	17.999	18.010	18.022	18.033	18.045	18.056	1,700
1,710	18.056	18.068	18.079	18.090	18.102	18.113	18.124	18.136	18.147	18.158	18.170	1,710
1,720	18.170	18.181	18.192	18.204	18.215	18.226	18.237	18.249	18.260	18.271	18.282	1,720
1,730	18.282	18.293	18.305	18.316	18.327	18.338	18.349	18.360	18.372	18.383	18.394	1,730
1,740	18.394	18.405	18.416	18.427	18.438	18.449	18.460	18.471	18.482	18.493	18.504	1,740
1,750	18.504	18.515	18.526	18.536	18.547	18.558	18.569	18.580	18.591	18.602	18.612	1,750
1,760	18.612	18.623	18.634	18.645	18.655	18.666	18.677	18.687	18.698			1,760
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type R Thermocouples Pt13% Rh - Pt

Temperature in Degrees Celsius

EMF in Absolute Millivolts — **Reference Junctions at 0 C**

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
-50	-0.226											-50
-40	-0.188	-0.192	-0.196	-0.200	-0.204	-0.207	-0.211	-0.215	-0.219	-0.223	-0.226	-40
-30	-0.145	-0.150	-0.154	-0.158	-0.163	-0.167	-0.171	-0.175	-0.180	-0.184	-0.188	-30
-20	-0.100	-0.105	-0.109	-0.114	-0.119	-0.123	-0.128	-0.132	-0.137	-0.141	-0.145	-20
-10	-0.051	-0.056	-0.061	-0.066	-0.071	-0.076	-0.081	-0.086	-0.091	-0.095	-0.100	-10
- 0	0.000	-0.005	-0.011	-0.016	-0.021	-0.026	-0.031	-0.036	-0.041	-0.046	-0.051	- 0
0	0.000	0.005	0.011	0.016	0.021	0.027	0.032	0.038	0.043	0.049	0.054	0
10	0.054	0.060	0.065	0.071	0.077	0.082	0.088	0.094	0.100	0.105	0.111	10
20	0.111	0.117	0.123	0.129	0.135	0.141	0.147	0.152	0.158	0.165	0.171	20
30	0.171	0.177	0.183	0.189	0.195	0.201	0.207	0.214	0.220	0.226	0.232	30
40	0.232	0.239	0.245	0.251	0.258	0.264	0.271	0.277	0.283	0.290	0.296	40
50	0.296	0.303	0.310	0.316	0.323	0.329	0.336	0.343	0.349	0.356	0.363	50
60	0.363	0.369	0.376	0.383	0.390	0.397	0.403	0.410	0.417	0.424	0.431	60
70	0.431	0.438	0.445	0.452	0.459	0.466	0.473	0.480	0.487	0.494	0.501	70
80	0.501	0.508	0.515	0.523	0.530	0.537	0.544	0.552	0.559	0.566	0.573	80
90	0.573	0.581	0.588	0.595	0.603	0.610	0.617	0.625	0.632	0.640	0.647	90
100	0.647	0.655	0.662	0.670	0.677	0.685	0.692	0.700	0.708	0.715	0.723	100
110	0.723	0.730	0.738	0.746	0.754	0.761	0.769	0.777	0.784	0.792	0.800	110
120	0.800	0.808	0.816	0.824	0.831	0.839	0.847	0.855	0.863	0.871	0.879	120
130	0.879	0.887	0.895	0.903	0.911	0.919	0.927	0.935	0.943	0.951	0.959	130
140	0.959	0.967	0.975	0.983	0.992	1.000	1.008	1.016	1.024	1.032	1.041	140
150	1.041	1.049	1.057	1.065	1.074	1.082	1.090	1.099	1.107	1.115	1.124	150
160	1.124	1.132	1.140	1.149	1.157	1.166	1.174	1.183	1.191	1.200	1.208	160
170	1.208	1.217	1.225	1.234	1.242	1.251	1.259	1.268	1.276	1.285	1.294	170
180	1.294	1.302	1.311	1.319	1.328	1.337	1.345	1.354	1.363	1.372	1.380	180
190	1.380	1.389	1.398	1.407	1.415	1.424	1.433	1.442	1.450	1.459	1.468	190
200	1.468	1.477	1.486	1.495	1.504	1.512	1.521	1.530	1.539	1.548	1.557	200
210	1.557	1.566	1.575	1.584	1.593	1.602	1.611	1.620	1.629	1.638	1.647	210
220	1.647	1.656	1.665	1.674	1.683	1.692	1.702	1.711	1.720	1.729	1.738	220
230	1.738	1.747	1.756	1.766	1.775	1.784	1.793	1.802	1.812	1.821	1.830	230
240	1.830	1.839	1.849	1.858	1.867	1.876	1.886	1.895	1.904	1.914	1.923	240
250	1.923	1.932	1.942	1.951	1.960	1.970	1.979	1.988	1.998	2.007	2.017	250
260	2.017	2.026	2.036	2.045	2.054	2.064	2.073	2.083	2.092	2.102	2.111	260
270	2.111	2.121	2.130	2.140	2.149	2.159	2.169	2.178	2.188	2.197	2.207	270
280	2.207	2.216	2.226	2.236	2.245	2.255	2.264	2.274	2.284	2.293	2.303	280
290	2.303	2.313	2.322	2.332	2.342	2.351	2.361	2.371	2.381	2.390	2.400	290
300	2.400	2.410	2.420	2.429	2.439	2.449	2.459	2.468	2.478	2.488	2.498	300
310	2.498	2.508	2.517	2.527	2.537	2.547	2.557	2.567	2.577	2.586	2.596	310
320	2.596	2.606	2.616	2.626	2.636	2.646	2.656	2.666	2.676	2.685	2.695	320
330	2.695	2.705	2.715	2.725	2.735	2.745	2.755	2.765	2.775	2.785	2.795	330
340	2.795	2.805	2.815	2.825	2.835	2.845	2.855	2.866	2.876	2.886	2.896	340
350	2.896	2.906	2.916	2.926	2.936	2.946	2.956	2.966	2.977	2.987	2.997	350
360	2.997	3.007	3.017	3.027	3.037	3.048	3.058	3.068	3.078	3.088	3.099	360
370	3.099	3.109	3.119	3.129	3.139	3.150	3.160	3.170	3.180	3.191	3.201	370
380	3.201	3.211	3.221	3.232	3.242	3.252	3.263	3.273	3.283	3.293	3.304	380
390	3.304	3.314	3.324	3.335	3.345	3.355	3.366	3.376	3.386	3.397	3.407	390
400	3.407	3.418	3.428	3.438	3.449	3.459	3.470	3.480	3.490	3.501	3.511	400
410	3.511	3.522	3.532	3.543	3.553	3.563	3.574	3.584	3.595	3.605	3.616	410
420	3.616	3.626	3.637	3.647	3.658	3.668	3.679	3.689	3.700	3.710	3.721	420
430	3.721	3.731	3.742	3.752	3.763	3.774	3.784	3.795	3.805	3.816	3.826	430
440	3.826	3.837	3.848	3.858	3.869	3.879	3.890	3.901	3.911	3.922	3.933	440
450	3.933	3.943	3.954	3.964	3.975	3.986	3.996	4.007	4.018	4.028	4.039	450
460	4.039	4.050	4.061	4.071	4.082	4.093	4.103	4.114	4.125	4.136	4.146	460
470	4.146	4.157	4.168	4.178	4.189	4.200	4.211	4.222	4.232	4.243	4.254	470
480	4.254	4.265	4.275	4.286	4.297	4.308	4.319	4.329	4.340	4.351	4.362	480
490	4.362	4.373	4.384	4.394	4.405	4.416	4.427	4.438	4.449	4.460	4.471	490
500	4.471	4.481	4.492	4.503	4.514	4.525	4.536	4.547	4.558	4.569	4.580	500
510	4.580	4.591	4.601	4.612	4.623	4.634	4.645	4.656	4.667	4.678	4.689	510
520	4.689	4.700	4.711	4.722	4.733	4.744	4.755	4.766	4.777	4.788	4.799	520
530	4.799	4.810	4.821	4.832	4.843	4.854	4.865	4.876	4.888	4.899	4.910	530
540	4.910	4.921	4.932	4.943	4.954	4.965	4.976	4.987	4.998	5.009	5.021	540
550	5.021	5.032	5.043	5.054	5.065	5.076	5.087	5.099	5.110	5.121	5.132	550
560	5.132	5.143	5.154	5.166	5.177	5.188	5.199	5.210	5.221	5.233	5.244	560
570	5.244	5.255	5.266	5.278	5.289	5.300	5.311	5.322	5.334	5.345	5.356	570
580	5.356	5.368	5.379	5.390	5.401	5.413	5.424	5.435	5.446	5.458	5.469	580
590	5.469	5.480	5.492	5.503	5.514	5.526	5.537	5.548	5.560	5.571	5.582	590
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type R Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — **Reference Junctions at 0 C**

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
600	5.582	5.594	5.605	5.616	5.628	5.639	5.650	5.662	5.673	5.685	5.696	600
610	5.696	5.707	5.719	5.730	5.742	5.753	5.764	5.776	5.787	5.799	5.810	610
620	5.810	5.821	5.833	5.844	5.856	5.867	5.879	5.890	5.902	5.913	5.925	620
630	5.925	5.936	5.948	5.959	5.971	5.982	5.994	6.005	6.017	6.028	6.040	630
640	6.040	6.051	6.063	6.074	6.086	6.098	6.109	6.121	6.132	6.144	6.155	640
650	6.155	6.167	6.179	6.190	6.202	6.213	6.225	6.237	6.248	6.260	6.272	650
660	6.272	6.283	6.295	6.307	6.318	6.330	6.342	6.353	6.365	6.377	6.388	660
670	6.388	6.400	6.412	6.423	6.435	6.447	6.458	6.470	6.482	6.494	6.505	670
680	6.505	6.517	6.529	6.541	6.552	6.564	6.576	6.588	6.599	6.611	6.623	680
690	6.623	6.635	6.647	6.658	6.670	6.682	6.694	6.706	6.718	6.729	6.741	690
700	6.741	6.753	6.765	6.777	6.789	6.800	6.812	6.824	6.836	6.848	6.860	700
710	6.860	6.872	6.884	6.895	6.907	6.919	6.931	6.943	6.955	6.967	6.979	710
720	6.979	6.991	7.003	7.015	7.027	7.039	7.051	7.063	7.074	7.086	7.098	720
730	7.098	7.110	7.122	7.134	7.146	7.158	7.170	7.182	7.194	7.206	7.218	730
740	7.218	7.231	7.243	7.255	7.267	7.279	7.291	7.303	7.315	7.327	7.339	740
750	7.339	7.351	7.363	7.375	7.387	7.399	7.412	7.424	7.436	7.448	7.460	750
760	7.460	7.472	7.484	7.496	7.509	7.521	7.533	7.545	7.557	7.569	7.582	760
770	7.582	7.594	7.606	7.618	7.630	7.642	7.655	7.667	7.679	7.691	7.703	770
780	7.703	7.716	7.728	7.740	7.752	7.765	7.777	7.789	7.801	7.814	7.826	780
790	7.826	7.838	7.850	7.863	7.875	7.887	7.900	7.912	7.924	7.937	7.949	790
800	7.949	7.961	7.973	7.986	7.998	8.010	8.023	8.035	8.047	8.060	8.072	800
810	8.072	8.085	8.097	8.109	8.122	8.134	8.146	8.159	8.171	8.184	8.196	810
820	8.196	8.208	8.221	8.233	8.246	8.258	8.271	8.283	8.295	8.308	8.320	820
830	8.320	8.333	8.345	8.358	8.370	8.383	8.395	8.408	8.420	8.433	8.445	830
840	8.445	8.458	8.470	8.483	8.495	8.508	8.520	8.533	8.545	8.558	8.570	840
850	8.570	8.583	8.595	8.608	8.621	8.633	8.646	8.658	8.671	8.683	8.696	850
860	8.696	8.709	8.721	8.734	8.746	8.759	8.772	8.784	8.797	8.810	8.822	860
870	8.822	8.835	8.847	8.860	8.873	8.885	8.898	8.911	8.923	8.936	8.949	870
880	8.949	8.961	8.974	8.987	9.000	9.012	9.025	9.038	9.050	9.063	9.076	880
890	9.076	9.089	9.101	9.114	9.127	9.140	9.152	9.165	9.178	9.191	9.203	890
900	9.203	9.216	9.229	9.242	9.254	9.267	9.280	9.293	9.306	9.319	9.331	900
910	9.331	9.344	9.357	9.370	9.383	9.395	9.408	9.421	9.434	9.447	9.460	910
920	9.460	9.473	9.485	9.498	9.511	9.524	9.537	9.550	9.563	9.576	9.589	920
930	9.589	9.602	9.614	9.627	9.640	9.653	9.666	9.679	9.692	9.705	9.718	930
940	9.718	9.731	9.744	9.757	9.770	9.783	9.796	9.809	9.822	9.835	9.848	940
950	9.848	9.861	9.874	9.887	9.900	9.913	9.926	9.939	9.952	9.965	9.978	950
960	9.978	9.991	10.004	10.017	10.030	10.043	10.056	10.069	10.082	10.095	10.109	960
970	10.109	10.122	10.135	10.148	10.161	10.174	10.187	10.200	10.213	10.227	10.240	970
980	10.240	10.253	10.266	10.279	10.292	10.305	10.319	10.332	10.345	10.358	10.371	980
990	10.371	10.384	10.398	10.411	10.424	10.437	10.450	10.464	10.477	10.490	10.503	990
1.000	10.503	10.516	10.530	10.543	10.556	10.569	10.583	10.596	10.609	10.622	10.636	1.000
1.010	10.636	10.649	10.662	10.675	10.689	10.702	10.715	10.729	10.742	10.755	10.768	1.010
1.020	10.768	10.782	10.795	10.808	10.822	10.835	10.848	10.862	10.875	10.888	10.902	1.020
1.030	10.902	10.915	10.928	10.942	10.955	10.968	10.982	10.995	11.009	11.022	11.035	1.030
1.040	11.035	11.049	11.062	11.076	11.089	11.102	11.116	11.129	11.143	11.156	11.170	1.040
1.050	11.170	11.183	11.196	11.210	11.223	11.237	11.250	11.264	11.277	11.291	11.304	1.050
1.060	11.304	11.318	11.331	11.345	11.358	11.372	11.385	11.399	11.412	11.426	11.439	1.060
1.070	11.439	11.453	11.466	11.480	11.493	11.507	11.520	11.534	11.547	11.561	11.574	1.070
1.080	11.574	11.588	11.602	11.615	11.629	11.642	11.656	11.669	11.683	11.697	11.710	1.080
1.090	11.710	11.724	11.737	11.751	11.765	11.778	11.792	11.805	11.819	11.833	11.846	1.090
1.100	11.846	11.860	11.874	11.887	11.901	11.914	11.928	11.942	11.955	11.969	11.983	1.100
1.110	11.983	11.996	12.010	12.024	12.037	12.051	12.065	12.078	12.092	12.106	12.119	1.110
1.120	12.119	12.133	12.147	12.161	12.174	12.188	12.202	12.215	12.229	12.243	12.257	1.120
1.130	12.257	12.270	12.284	12.298	12.311	12.325	12.339	12.353	12.366	12.380	12.394	1.130
1.140	12.394	12.408	12.421	12.435	12.449	12.463	12.476	12.490	12.504	12.518	12.532	1.140
1.150	12.532	12.545	12.559	12.573	12.587	12.600	12.614	12.628	12.642	12.656	12.669	1.150
1.160	12.669	12.683	12.697	12.711	12.725	12.739	12.752	12.766	12.780	12.794	12.808	1.160
1.170	12.808	12.822	12.835	12.849	12.863	12.877	12.891	12.905	12.918	12.932	12.946	1.170
1.180	12.946	12.960	12.974	12.988	13.002	13.016	13.029	13.043	13.057	13.071	13.085	1.180
1.190	13.085	13.099	13.113	13.127	13.140	13.154	13.168	13.182	13.196	13.210	13.224	1.190
1.200	13.224	13.238	13.252	13.266	13.280	13.293	13.307	13.321	13.335	13.349	13.363	1.200
1.210	13.363	13.377	13.391	13.405	13.419	13.433	13.447	13.461	13.475	13.489	13.502	1.210
1.220	13.502	13.516	13.530	13.544	13.558	13.572	13.586	13.600	13.614	13.628	13.642	1.220
1.230	13.642	13.656	13.670	13.684	13.698	13.712	13.726	13.740	13.754	13.768	13.782	1.230
1.240	13.782	13.796	13.810	13.824	13.838	13.852	13.866	13.880	13.894	13.908	13.922	1.240
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type J Thermocouples. Iron/Copper-Nickel

Temperature in Degrees Celsius

EMF in Absolute Millivolts — **Reference Junctions at 0 C**

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
-210	-8.096											-210
-200	-7.890	-7.912	-7.934	-7.955	-7.976	-7.996	-8.017	-8.037	-8.057	-8.076	-8.096	-200
-190	-7.659	-7.683	-7.707	-7.731	-7.755	-7.778	-7.801	-7.824	-7.846	-7.868	-7.890	-190
-180	-7.402	-7.429	-7.455	-7.482	-7.508	-7.533	-7.559	-7.584	-7.609	-7.634	-7.659	-180
-170	-7.122	-7.151	-7.180	-7.209	-7.237	-7.265	-7.293	-7.321	-7.348	-7.375	-7.402	-170
-160	-6.821	-6.852	-6.883	-6.914	-6.944	-6.974	-7.004	-7.034	-7.064	-7.093	-7.122	-160
-150	-6.499	-6.532	-6.565	-6.598	-6.630	-6.663	-6.695	-6.727	-6.758	-6.790	-6.821	-150
-140	-6.159	-6.194	-6.228	-6.263	-6.297	-6.331	-6.365	-6.399	-6.433	-6.466	-6.499	-140
-130	-5.801	-5.837	-5.874	-5.910	-5.946	-5.982	-6.018	-6.053	-6.089	-6.124	-6.159	-130
-120	-5.426	-5.464	-5.502	-5.540	-5.578	-5.615	-5.653	-5.690	-5.727	-5.764	-5.801	-120
-110	-5.036	-5.076	-5.115	-5.155	-5.194	-5.233	-5.272	-5.311	-5.349	-5.388	-5.426	-110
-100	-4.632	-4.673	-4.714	-4.755	-4.795	-4.836	-4.876	-4.916	-4.956	-4.996	-5.036	-100
-90	-4.215	-4.257	-4.299	-4.341	-4.383	-4.425	-4.467	-4.508	-4.550	-4.591	-4.632	-90
-80	-3.785	-3.829	-3.872	-3.915	-3.958	-4.001	-4.044	-4.087	-4.130	-4.172	-4.215	-80
-70	-3.344	-3.389	-3.433	-3.478	-3.522	-3.566	-3.610	-3.654	-3.698	-3.742	-3.785	-70
-60	-2.892	-2.938	-2.984	-3.029	-3.074	-3.120	-3.165	-3.210	-3.255	-3.299	-3.344	-60
-50	-2.431	-2.478	-2.524	-2.570	-2.617	-2.663	-2.709	-2.755	-2.801	-2.847	-2.892	-50
-40	-1.960	-2.008	-2.055	-2.102	-2.150	-2.197	-2.244	-2.291	-2.338	-2.384	-2.431	-40
-30	-1.481	-1.530	-1.578	-1.626	-1.674	-1.722	-1.770	-1.818	-1.865	-1.913	-1.960	-30
-20	-0.995	-1.044	-1.093	-1.141	-1.190	-1.239	-1.288	-1.336	-1.385	-1.433	-1.481	-20
-10	-0.501	-0.550	-0.600	-0.650	-0.699	-0.748	-0.798	-0.847	-0.896	-0.945	-0.995	-10
- 0	0.000	-0.050	-0.101	-0.151	-0.201	-0.251	-0.301	-0.351	-0.401	-0.451	-0.501	- 0
0	0.000	0.050	0.101	0.151	0.202	0.253	0.303	0.354	0.405	0.456	0.507	0
10	0.507	0.558	0.609	0.660	0.711	0.762	0.813	0.865	0.916	0.967	1.019	10
20	1.019	1.070	1.122	1.174	1.225	1.277	1.329	1.381	1.432	1.484	1.536	20
30	1.536	1.588	1.640	1.693	1.745	1.797	1.849	1.901	1.954	2.006	2.058	30
40	2.058	2.111	2.163	2.216	2.268	2.321	2.374	2.426	2.479	2.532	2.585	40
50	2.585	2.638	2.691	2.743	2.796	2.849	2.902	2.956	3.009	3.062	3.115	50
60	3.115	3.168	3.221	3.275	3.328	3.381	3.435	3.488	3.542	3.595	3.649	60
70	3.649	3.702	3.756	3.809	3.863	3.917	3.971	4.024	4.078	4.132	4.186	70
80	4.186	4.239	4.293	4.347	4.401	4.455	4.509	4.563	4.617	4.671	4.725	80
90	4.725	4.780	4.834	4.888	4.942	4.996	5.050	5.105	5.159	5.213	5.268	90
100	5.268	5.322	5.376	5.431	5.485	5.540	5.594	5.649	5.703	5.758	5.812	100
110	5.812	5.867	5.921	5.976	6.031	6.085	6.140	6.195	6.249	6.304	6.359	110
120	6.359	6.414	6.468	6.523	6.578	6.633	6.688	6.742	6.797	6.852	6.907	120
130	6.907	6.962	7.017	7.072	7.127	7.182	7.237	7.292	7.347	7.402	7.457	130
140	7.457	7.512	7.567	7.622	7.677	7.732	7.787	7.843	7.898	7.953	8.008	140
150	8.008	8.063	8.118	8.174	8.229	8.284	8.339	8.394	8.450	8.505	8.560	150
160	8.560	8.616	8.671	8.726	8.781	8.837	8.892	8.947	9.003	9.058	9.113	160
170	9.113	9.169	9.224	9.279	9.335	9.390	9.446	9.501	9.556	9.612	9.667	170
180	9.667	9.723	9.778	9.834	9.889	9.944	10.000	10.055	10.111	10.166	10.222	180
190	10.222	10.277	10.333	10.388	10.444	10.499	10.555	10.610	10.666	10.721	10.777	190
200	10.777	10.832	10.888	10.943	10.999	11.054	11.110	11.165	11.221	11.276	11.332	200
210	11.332	11.387	11.443	11.498	11.554	11.609	11.665	11.720	11.776	11.831	11.887	210
220	11.887	11.943	11.998	12.054	12.109	12.165	12.220	12.276	12.331	12.387	12.442	220
230	12.442	12.498	12.553	12.609	12.664	12.720	12.776	12.831	12.887	12.942	12.998	230
240	12.998	13.053	13.109	13.164	13.220	13.275	13.331	13.386	13.442	13.497	13.553	240
250	13.553	13.608	13.664	13.719	13.775	13.830	13.886	13.941	13.997	14.052	14.108	250
260	14.108	14.163	14.219	14.274	14.330	14.385	14.441	14.496	14.552	14.607	14.663	260
270	14.663	14.718	14.774	14.829	14.885	14.940	14.995	15.051	15.106	15.162	15.217	270
280	15.217	15.273	15.328	15.383	15.439	15.494	15.550	15.605	15.661	15.716	15.771	280
290	15.771	15.827	15.882	15.938	15.993	16.048	16.104	16.159	16.214	16.270	16.325	290
300	16.325	16.380	16.436	16.491	16.547	16.602	16.657	16.713	16.768	16.823	16.879	300
310	16.879	16.934	16.989	17.044	17.100	17.155	17.210	17.266	17.321	17.376	17.432	310
320	17.432	17.487	17.542	17.597	17.653	17.708	17.763	17.818	17.874	17.929	17.984	320
330	17.984	18.039	18.095	18.150	18.205	18.260	18.316	18.371	18.426	18.481	18.537	330
340	18.537	18.592	18.647	18.702	18.757	18.813	18.868	18.923	18.978	19.033	19.089	340
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type J Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — **Reference Junctions at 0 C**

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
350	19.089	19.144	19.199	19.254	19.309	19.364	19.420	19.475	19.530	19.585	19.640	350
360	19.640	19.695	19.751	19.806	19.861	19.916	19.971	20.026	20.081	20.137	20.192	360
370	20.192	20.247	20.302	20.357	20.412	20.467	20.523	20.578	20.633	20.688	20.743	370
380	20.743	20.798	20.853	20.909	20.964	21.019	21.074	21.129	21.184	21.239	21.295	380
390	21.295	21.350	21.405	21.460	21.515	21.570	21.625	21.680	21.736	21.791	21.846	390
400	21.846	21.901	21.956	22.011	22.066	22.122	22.177	22.232	22.287	22.342	22.397	400
410	22.397	22.453	22.508	22.563	22.618	22.673	22.728	22.784	22.839	22.894	22.949	410
420	22.949	23.004	23.060	23.115	23.170	23.225	23.280	23.336	23.391	23.446	23.501	420
430	23.501	23.556	23.612	23.667	23.722	23.777	23.833	23.888	23.943	23.999	24.054	430
440	24.054	24.109	24.164	24.220	24.275	24.330	24.386	24.441	24.496	24.552	24.607	440
450	24.607	24.662	24.718	24.773	24.829	24.884	24.939	24.995	25.050	25.106	25.161	450
460	25.161	25.217	25.272	25.327	25.383	25.438	25.494	25.549	25.605	25.661	25.716	460
470	25.716	25.772	25.827	25.883	25.938	25.994	26.050	26.105	26.161	26.216	26.272	470
480	26.272	26.328	26.383	26.439	26.495	26.551	26.606	26.662	26.718	26.774	26.829	480
490	26.829	26.885	26.941	26.997	27.053	27.109	27.165	27.220	27.276	27.332	27.388	490
500	27.388	27.444	27.500	27.556	27.612	27.668	27.724	27.780	27.836	27.893	27.949	500
510	27.949	28.005	28.061	28.117	28.173	28.230	28.286	28.342	28.398	28.455	28.511	510
520	28.511	28.567	28.624	28.680	28.736	28.793	28.849	28.906	28.962	29.019	29.075	520
530	29.075	29.132	29.188	29.245	29.301	29.358	29.415	29.471	29.528	29.585	29.642	530
540	29.642	29.698	9.755	29.812	29.869	29.926	29.983	30.039	30.096	30.153	30.210	540
550	30.210	30.267	30.324	30.381	30.439	30.496	30.553	30.610	30.667	30.724	30.782	550
560	30.782	.0.839	30.896	30.954	31.011	31.068	31.126	31.183	31.241	31.298	31.356	560
570	31.356	31.413	31.471	31.528	31.586	31.644	31.702	31.759	31.817	31.875	31.933	570
580	31.933	31.991	32.048	32.106	32.164	32.222	32.280	32.338	32.396	32.455	32.513	580
590	32.513	32.571	32.629	32.687	32.746	32.804	32.862	32.921	32.979	33.038	33.096	590
600	33.096	33.155	33.213	33.272	33.330	33.389	33.448	33.506	33.565	33.624	33.683	600
610	33.683	33.742	33.800	33.859	33.918	33.977	34.036	34.095	34.155	34.214	34.273	610
620	34.273	34.332	34.391	34.451	34.510	34.569	34.629	34.688	34.748	34.807	34.867	620
630	34.867	34.926	34.986	35.046	35.105	35.165	35.225	35.285	35.344	35.404	35.464	630
640	35.464	35.524	35.584	35.644	35.704	35.764	35.825	35.885	35.945	36.005	36.066	640
650	36.066	36.126	36.186	36.247	36.307	36.368	36.428	36.489	36.549	36.610	36.671	650
660	36.671	36.732	36.792	36.853	36.914	36.975	37.036	37.097	37.158	37.219	37.280	660
670	37.280	37.341	37.402	37.463	37.525	37.586	37.647	37.709	37.770	37.831	37.893	670
680	37.893	37.954	38.016	38.078	38.139	38.201	38.262	38.324	38.386	38.448	38.510	680
690	38.510	38.572	38.633	38.695	38.757	38.819	38.882	38.944	39.006	39.068	39.130	690
700	39.130	39.192	39.255	39.317	39.379	39.442	39.504	39.567	39.629	39.692	39.754	700
710	39.754	39.817	39.880	39.942	40.005	40.068	40.131	40.193	40.256	40.319	40.382	710
720	40.382	40.445	40.508	40.571	40.634	40.697	40.760	40.823	40.886	40.950	41.013	720
730	41.013	41.076	41.139	41.203	41.266	41.329	41.393	41.456	41.520	41.583	41.647	730
740	41.647	41.710	41.774	41.837	41.901	41.965	42.028	42.092	42.156	42.219	42.283	740
750	42.283	42.347	42.411	42.475	42.538	42.602	42.666	42.730	42.794	42.858	42.922	750
760	42.922	42.986	43.050	43.114	43.178	43.242	43.306	43.370	43.435	43.499	43.563	760
770	43.563	43.627	43.692	43.756	43.820	43.885	43.949	44.014	44.078	44.142	44.207	770
780	44.207	44.271	44.336	44.400	44.465	44.529	44.594	44.658	44.723	44.788	44.852	780
790	44.852	44.917	44.981	45.046	45.111	45.175	45.240	45.304	45.369	45.434	45.498	790
800	45.498	45.563	45.627	45.692	45.757	45.821	45.886	45.950	46.015	46.080	46.144	800
810	46.144	46.209	46.273	46.338	46.403	46.467	46.532	46.596	46.661	46.725	46.790	810
820	46.790	46.854	46.919	46.983	47.047	47.112	47.176	47.241	47.305	47.369	47.434	820
830	47.434	47.498	47.562	47.627	47.691	47.755	47.819	47.884	47.948	48.012	48.076	830
840	48.076	48.140	48.204	48.269	48.333	48.397	48.461	48.525	48.589	48.653	48.716	840
850	48.716	48.780	48.844	48.908	48.972	49.036	49.099	49.163	49.227	49.291	49.354	850
860	49.354	49.418	49.481	49.545	49.608	49.672	49.735	49.799	49.862	49.926	49.989	860
870	49.989	50.052	50.116	50.179	50.242	50.305	50.369	50.432	50.495	50.558	50.621	870
880	50.621	50.684	50.747	50.810	50.873	50.936	50.998	51.061	51.124	51.187	51.249	880
890	51.249	51.312	51.375	51.437	51.500	51.562	51.625	51.687	51.750	51.812	51.875	890
900	51.875	51.937	51.999	52.061	52.124	52.186	52.248	52.310	52.372	52.434	52.496	900
910	52.496	52.558	52.620	52.682	52.744	52.806	52.868	52.929	52.991	53.053	53.115	910
920	53.115	53.176	53.238	53.299	53.361	53.422	53.484	53.545	53.607	53.668	53.729	920
930	53.729	53.791	53.852	53.913	53.974	54.035	54.096	54.157	54.219	54.280	54.341	930
940	54.341	54.401	54.462	54.523	54.584	54.645	54.706	54.766	54.827	54.888	54.948	940
950	54.948	55.009	55.070	55.130	55.191	55.251	55.312	55.372	55.432	55.493	55.553	950
960	55.553	55.613	55.674	55.734	55.794	55.854	55.914	55.974	56.035	56.095	56.155	960
970	56.155	56.215	56.275	56.334	56.394	56.454	56.514	56.574	56.634	56.693	56.753	970
980	56.753	56.813	56.873	56.932	56.992	57.051	57.111	57.170	57.230	57.289	57.349	980
990	57.349	57.408	57.468	57.527	57.586	57.646	57.705	57.764	57.824	57.883	57.942	990
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type T Thermocouples. Copper/Copper-Nickel

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
-270	-6.258											-270
-260	-6.232	-6.236	-6.239	-6.242	-6.245	-6.248	-6.251	-6.253	-6.255	-6.256	-6.258	-260
-250	-6.181	-6.187	-6.193	-6.198	-6.204	-6.209	-6.214	-6.219	-6.224	-6.228	-6.232	-250
-240	-6.105	-6.114	-6.122	-6.130	-6.138	-6.146	-6.153	-6.160	-6.167	-6.174	-6.181	-240
-230	-6.007	-6.018	-6.028	-6.039	-6.049	-6.059	-6.068	-6.078	-6.087	-6.096	-6.105	-230
-220	-5.889	-5.901	-5.914	-5.926	-5.938	-5.950	-5.962	-5.973	-5.985	-5.996	-6.007	-220
-210	-5.753	-5.767	-5.782	-5.795	-5.809	-5.823	-5.836	-5.850	-5.863	-5.876	-5.889	-210
-200	-5.603	-5.619	-5.634	-5.650	-5.665	-5.680	-5.695	-5.710	-5.724	-5.739	-5.753	-200
-190	-5.439	-5.456	-5.473	-5.489	-5.506	-5.522	-5.539	-5.555	-5.571	-5.587	-5.603	-190
-180	-5.261	-5.279	-5.297	-5.315	-5.333	-5.351	-5.369	-5.387	-5.404	-5.421	-5.439	-180
-170	-5.069	-5.089	-5.109	-5.128	-5.147	-5.167	-5.186	-5.205	-5.223	-5.242	-5.261	-170
-160	-4.865	-4.886	-4.907	-4.928	-4.948	-4.969	-4.989	-5.010	-5.030	-5.050	-5.069	-160
-150	-4.648	-4.670	-4.693	-4.715	-4.737	-4.758	-4.780	-4.801	-4.823	-4.844	-4.865	-150
-140	-4.419	-4.442	-4.466	-4.489	-4.512	-4.535	-4.558	-4.581	-4.603	-4.626	-4.648	-140
-130	-4.177	-4.202	-4.226	-4.251	-4.275	-4.299	-4.323	-4.347	-4.371	-4.395	-4.419	-130
-120	-3.923	-3.949	-3.976	-4.000	-4.026	-4.051	-4.077	-4.102	-4.127	-4.152	-4.177	-120
-110	-3.656	-3.684	-3.711	-3.737	-3.764	-3.791	-3.818	-3.844	-3.870	-3.897	-3.923	-110
-100	-3.378	-3.407	-3.435	-3.463	-3.491	-3.519	-3.547	-3.574	-3.602	-3.629	-3.656	-100
-90	-3.089	-3.118	-3.147	-3.177	-3.206	-3.235	-3.264	-3.293	-3.321	-3.350	-3.378	-90
-80	-2.788	-2.818	-2.849	-2.879	-2.909	-2.939	-2.970	-2.999	-3.029	-3.059	-3.089	-80
-70	-2.475	-2.507	-2.539	-2.570	-2.602	-2.633	-2.664	-2.695	-2.726	-2.757	-2.788	-70
-60	-2.152	-2.185	-2.218	-2.250	-2.283	-2.315	-2.348	-2.380	-2.412	-2.444	-2.475	-60
-50	-1.819	-1.853	-1.886	-1.920	-1.953	-1.987	-2.020	-2.053	-2.087	-2.120	-2.152	-50
-40	-1.475	-1.510	-1.544	-1.579	-1.614	-1.648	-1.682	-1.717	-1.751	-1.785	-1.819	-40
-30	-1.121	-1.157	-1.192	-1.228	-1.263	-1.299	-1.334	-1.370	-1.405	-1.440	-1.475	-30
-20	-0.757	-0.794	-0.830	-0.867	-0.903	-0.940	-0.976	-1.013	-1.049	-1.085	-1.121	-20
-10	-0.383	-0.421	-0.458	-0.496	-0.534	-0.571	-0.608	-0.646	-0.683	-0.720	-0.757	-10
- 0	0.000	-0.039	-0.077	-0.116	-0.154	-0.193	-0.231	-0.269	-0.307	-0.345	-0.383	- 0
0	0.000	0.039	0.078	0.117	0.156	0.195	0.234	0.273	0.312	0.351	0.391	0
10	0.391	0.430	0.470	0.510	0.549	0.589	0.629	0.669	0.709	0.749	0.789	10
20	0.789	0.830	0.870	0.911	0.951	0.992	1.032	1.073	1.114	1.155	1.196	20
30	1.196	1.237	1.279	1.320	1.361	1.403	1.444	1.486	1.528	1.569	1.611	30
40	1.611	1.653	1.695	1.738	1.780	1.822	1.865	1.907	1.950	1.992	2.035	40
50	2.035	2.078	2.121	2.164	2.207	2.250	2.294	2.337	2.380	2.424	2.467	50
60	2.467	2.511	2.555	2.599	2.643	2.687	2.731	2.775	2.819	2.864	2.908	60
70	2.908	2.953	2.997	3.042	3.087	3.131	3.176	3.221	3.266	3.312	3.357	70
80	3.357	3.402	3.447	3.493	3.538	3.584	3.630	3.676	3.721	3.767	3.813	80
90	3.813	3.859	3.906	3.952	3.998	4.044	4.091	4.137	4.184	4.231	4.277	90
100	4.277	4.324	4.371	4.418	4.465	4.512	4.559	4.607	4.654	4.701	4.749	100
110	4.749	4.796	4.844	4.891	4.939	4.987	5.035	5.083	5.131	5.179	5.227	110
120	5.227	5.275	5.324	5.372	5.420	5.469	5.517	5.566	5.615	5.663	5.712	120
130	5.712	5.761	5.810	5.859	5.908	5.957	6.007	6.056	6.105	6.155	6.204	130
140	6.204	6.254	6.303	6.353	6.403	6.452	6.502	6.552	6.602	6.652	6.702	140
150	6.702	6.753	6.803	6.853	6.903	6.954	7.004	7.055	7.106	7.156	7.207	150
160	7.207	7.258	7.309	7.360	7.411	7.462	7.513	7.564	7.615	7.666	7.718	160
170	7.718	7.769	7.821	7.872	7.924	7.975	8.027	8.079	8.131	8.183	8.235	170
180	8.235	8.287	8.339	8.391	8.443	8.495	8.548	8.600	8.652	8.705	8.757	180
190	8.757	8.810	8.863	8.915	8.968	9.021	9.074	9.127	9.180	9.233	9.286	190
200	9.286	9.339	9.392	9.446	9.499	9.553	9.606	9.659	9.713	9.767	9.820	200
210	9.820	9.874	9.928	9.982	10.036	10.090	10.144	10.198	10.252	10.306	10.360	210
220	10.360	10.414	10.469	10.523	10.578	10.632	10.687	10.741	10.796	10.851	10.905	220
230	10.905	10.960	11.015	11.070	11.125	11.180	11.235	11.290	11.345	11.401	11.456	230
240	11.456	11.511	11.566	11.622	11.677	11.733	11.788	11.844	11.900	11.956	12.011	240
250	12.011	12.067	12.123	12.179	12.235	12.291	12.347	12.403	12.459	12.515	12.572	250
260	12.572	12.628	12.684	12.741	12.797	12.854	12.910	12.967	13.024	13.080	13.137	260
270	13.137	13.194	13.251	13.307	13.364	13.421	13.478	13.535	13.592	13.650	13.707	270
280	13.707	13.764	13.821	13.879	13.936	13.993	14.051	14.108	14.166	14.223	14.281	280
290	14.281	14.339	14.396	14.454	14.512	14.570	14.628	14.686	14.744	14.802	14.860	290
300	14.860	14.918	14.976	15.034	15.092	15.151	15.209	15.267	15.326	15.384	15.443	300
310	15.443	15.501	15.560	15.619	15.677	15.736	15.795	15.853	15.912	15.971	16.030	310
320	16.030	16.089	16.148	16.207	16.266	16.325	16.384	16.444	16.503	16.562	16.621	320
330	16.621	16.681	16.740	16.800	16.859	16.919	16.978	17.038	17.097	17.157	17.217	330
340	17.217	17.277	17.336	17.396	17.456	17.516	17.576	17.636	17.696	17.756	17.816	340
350	17.816	17.877	17.937	17.997	18.057	18.118	18.178	18.238	18.299	18.359	18.420	350
360	18.420	18.480	18.541	18.602	18.662	18.723	18.784	18.845	18.905	18.966	19.027	360
370	19.027	19.088	19.149	19.210	19.271	19.332	19.393	19.455	19.516	19.577	19.638	370
380	19.638	19.699	19.761	19.822	19.883	19.945	20.006	20.068	20.129	20.191	20.252	380
390	20.252	20.314	20.376	20.437	20.499	20.560	20.622	20.684	20.746	20.807	20.869	390
400	20.869											400
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type E Thermocouples. Nickel-Chromium/Copper-Nickel

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS												
-270	-9.835											-270
-260	-9.797	-9.802	-9.808	-9.813	-9.817	-9.821	-9.825	-9.828	-9.831	-9.833	-9.835	-260
-250	-9.719	-9.728	-9.737	-9.746	-9.754	-9.762	-9.770	-9.777	-9.784	-9.791	-9.797	-250
-240	-9.604	-9.617	-9.630	-9.642	-9.654	-9.666	-9.677	-9.688	-9.699	-9.709	-9.719	-240
-230	-9.455	-9.472	-9.488	-9.503	-9.519	-9.534	-9.549	-9.563	-9.577	-9.591	-9.604	-230
-220	-9.274	-9.293	-9.313	-9.332	-9.350	-9.368	-9.386	-9.404	-9.421	-9.438	-9.455	-220
-210	-9.063	-9.085	-9.107	-9.129	-9.151	-9.172	-9.193	-9.214	-9.234	-9.254	-9.274	-210
-200	-8.824	-8.850	-8.874	-8.899	-8.923	-8.947	-8.971	-8.994	-9.017	-9.040	-9.063	-200
-190	-8.561	-8.588	-8.615	-8.642	-8.669	-8.696	-8.722	-8.748	-8.774	-8.799	-8.824	-190
-180	-8.273	-8.303	-8.333	-8.362	-8.391	-8.420	-8.449	-8.477	-8.505	-8.533	-8.561	-180
-170	-7.963	-7.995	-8.027	-8.058	-8.090	-8.121	-8.152	-8.183	-8.213	-8.243	-8.273	-170
-160	-7.631	-7.665	-7.699	-7.733	-7.767	-7.800	-7.833	-7.866	-7.898	-7.931	-7.963	-160
-150	-7.279	-7.315	-7.351	-7.387	-7.422	-7.458	-7.493	-7.528	-7.562	-7.597	-7.631	-150
-140	-6.907	-6.945	-6.983	-7.020	-7.058	-7.095	-7.132	-7.169	-7.206	-7.243	-7.279	-140
-130	-6.516	-6.556	-6.596	-6.635	-6.675	-6.714	-6.753	-6.792	-6.830	-6.869	-6.907	-130
-120	-6.107	-6.149	-6.190	-6.231	-6.273	-6.314	-6.354	-6.395	-6.436	-6.476	-6.516	-120
-110	-5.680	-5.724	-5.767	-5.810	-5.853	-5.896	-5.938	-5.981	-6.023	-6.065	-6.107	-110
-100	-5.237	-5.282	-5.327	-5.371	-5.416	-5.460	-5.505	-5.549	-5.593	-5.637	-5.680	-100
-90	-4.777	-4.824	-4.870	-4.916	-4.963	-5.009	-5.055	-5.100	-5.146	-5.191	-5.237	-90
-80	-4.301	-4.350	-4.398	-4.446	-4.493	-4.541	-4.588	-4.636	-4.683	-4.730	-4.777	-80
-70	-3.811	-3.860	-3.910	-3.959	-4.009	-4.058	-4.107	-4.156	-4.204	-4.253	-4.301	-70
-60	-3.306	-3.357	-3.408	-3.459	-3.509	-3.560	-3.610	-3.661	-3.711	-3.761	-3.811	-60
-50	-2.787	-2.839	-2.892	-2.944	-2.996	-3.048	-3.100	-3.152	-3.203	-3.254	-3.306	-50
-40	-2.254	-2.308	-2.362	-2.416	-2.469	-2.522	-2.575	-2.628	-2.681	-2.734	-2.787	-40
-30	-1.709	-1.764	-1.819	-1.874	-1.929	-1.983	-2.038	-2.092	-2.146	-2.200	-2.254	-30
-20	-1.151	-1.208	-1.264	-1.320	-1.376	-1.432	-1.487	-1.543	-1.599	-1.654	-1.709	-20
-10	-0.581	-0.639	-0.696	-0.754	-0.811	-0.868	-0.925	-0.982	-1.038	-1.095	-1.151	-10
- 0	0.000	-0.059	-0.117	-0.176	-0.234	-0.292	-0.350	-0.408	-0.466	-0.524	-0.581	- 0
0	0.000	0.059	0.118	0.176	0.235	0.295	0.354	0.413	0.472	0.532	0.591	0
10	0.591	0.651	0.711	0.770	0.830	0.890	0.950	1.011	1.071	1.131	1.192	10
20	1.192	1.252	1.313	1.373	1.434	1.495	1.556	1.617	1.678	1.739	1.801	20
30	1.801	1.862	1.924	1.985	2.047	2.109	2.171	2.233	2.295	2.357	2.419	30
40	2.419	2.482	2.544	2.607	2.669	2.732	2.795	2.858	2.921	2.984	3.047	40
50	3.047	3.110	3.173	3.237	3.300	3.364	3.428	3.491	3.555	3.619	3.683	50
60	3.683	3.748	3.812	3.876	3.941	4.005	4.070	4.134	4.199	4.264	4.329	60
70	4.329	4.394	4.459	4.524	4.590	4.655	4.720	4.786	4.852	4.917	4.983	70
80	4.983	5.049	5.115	5.181	5.247	5.314	5.380	5.446	5.513	5.579	5.646	80
90	5.646	5.713	5.780	5.846	5.913	5.981	6.048	6.115	6.182	6.250	6.317	90
100	6.317	6.385	6.452	6.520	6.588	6.656	6.724	6.792	6.860	6.928	6.996	100
110	6.996	7.064	7.133	7.201	7.270	7.339	7.407	7.476	7.545	7.614	7.683	110
120	7.683	7.752	7.821	7.890	7.960	8.029	8.099	8.168	8.238	8.307	8.377	120
130	8.377	8.447	8.517	8.587	8.657	8.727	8.797	8.867	8.938	9.008	9.078	130
140	9.078	9.149	9.220	9.290	9.361	9.432	9.503	9.573	9.644	9.715	9.787	140
150	9.787	9.858	9.929	10.000	10.072	10.143	10.215	10.286	10.358	10.429	10.501	150
160	10.501	10.573	10.645	10.717	10.789	10.861	10.933	11.005	11.077	11.150	11.222	160
170	11.222	11.294	11.367	11.439	11.512	11.585	11.657	11.730	11.803	11.876	11.949	170
180	11.949	12.022	12.095	12.168	12.241	12.314	12.387	12.461	12.534	12.608	12.681	180
190	12.681	12.755	12.828	12.902	12.975	13.049	13.123	13.197	13.271	13.345	13.419	190
200	13.419	13.493	13.567	13.641	13.715	13.789	13.864	13.938	14.012	14.087	14.161	200
210	14.161	14.236	14.310	14.385	14.460	14.534	14.609	14.684	14.759	14.834	14.909	210
220	14.909	14.984	15.059	15.134	15.209	15.284	15.359	15.435	15.510	15.585	15.661	220
230	15.661	15.736	15.812	15.887	15.963	16.038	16.114	16.190	16.266	16.341	16.417	230
240	16.417	16.493	16.569	16.645	16.721	16.797	16.873	16.949	17.025	17.101	17.178	240
250	17.178	17.254	17.330	17.406	17.483	17.559	17.636	17.712	17.789	17.865	17.942	250
260	17.942	18.018	18.095	18.172	18.248	18.325	18.402	18.479	18.556	18.633	18.710	260
270	18.710	18.787	18.864	18.941	19.018	19.095	19.172	19.249	19.326	19.404	19.481	270
280	19.481	19.558	19.636	19.713	19.790	19.868	19.945	20.023	20.100	20.178	20.256	280
290	20.256	20.333	20.411	20.488	20.566	20.644	20.722	20.800	20.877	20.955	21.033	290
300	21.033	21.111	21.189	21.267	21.345	21.423	21.501	21.579	21.657	21.735	21.814	300
310	21.814	21.892	21.970	22.048	22.127	22.205	22.283	22.362	22.440	22.518	22.597	310
320	22.597	22.675	22.754	22.832	22.911	22.989	23.068	23.147	23.225	23.304	23.383	320
330	23.383	23.461	23.540	23.619	23.698	23.777	23.855	23.934	24.013	24.092	24.171	330
340	24.171	24.250	24.329	24.408	24.487	24.566	24.645	24.724	24.803	24.882	24.961	340
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type E Thermocouples *Continued*

Temperature in Degrees Celsius

EMF in Absolute Millivolts — Reference Junctions at 0 C

DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C
	THERMOELECTRIC VOLTAGE IN ABSOLUTE MILLIVOLTS											
330	29.961	29.841	29.720	29.599	29.478	29.357	29.237	29.116	28.995	28.875	28.754	330
340	29.754	29.633	29.512	29.392	29.271	29.150	29.029	28.908	28.788	28.667	28.546	340
350	29.546	29.425	29.304	29.183	29.062	28.941	28.820	28.699	28.578	28.457	28.336	350
360	29.337	29.216	29.095	28.974	28.853	28.732	28.611	28.490	28.369	28.248	28.127	360
370	29.127	29.006	28.885	28.764	28.643	28.522	28.401	28.280	28.159	28.038	27.917	370
380	28.916	28.795	28.674	28.553	28.432	28.311	28.190	28.069	27.948	27.827	27.706	380
390	28.705	28.584	28.463	28.342	28.221	28.100	27.979	27.858	27.737	27.616	27.495	390
400	28.493	28.372	28.251	28.130	28.009	27.888	27.767	27.646	27.525	27.404	27.283	400
410	28.281	28.160	28.039	27.918	27.797	27.676	27.555	27.434	27.313	27.192	27.071	410
420	28.068	27.947	27.826	27.705	27.584	27.463	27.342	27.221	27.100	26.979	26.858	420
430	27.855	27.734	27.613	27.492	27.371	27.250	27.129	27.008	26.887	26.766	26.645	430
440	27.642	27.521	27.400	27.279	27.158	27.037	26.916	26.795	26.674	26.553	26.432	440
450	27.428	27.307	27.186	27.065	26.944	26.823	26.702	26.581	26.460	26.339	26.218	450
460	27.214	27.093	26.972	26.851	26.730	26.609	26.488	26.367	26.246	26.125	26.004	460
470	26.999	26.878	26.757	26.636	26.515	26.394	26.273	26.152	26.031	25.910	25.789	470
480	26.784	26.663	26.542	26.421	26.300	26.179	26.058	25.937	25.816	25.695	25.574	480
490	26.568	26.447	26.326	26.205	26.084	25.963	25.842	25.721	25.600	25.479	25.358	490
500	26.352	26.231	26.110	25.989	25.868	25.747	25.626	25.505	25.384	25.263	25.142	500
510	26.136	26.015	25.894	25.773	25.652	25.531	25.410	25.289	25.168	25.047	24.926	510
520	25.919	25.798	25.677	25.556	25.435	25.314	25.193	25.072	24.951	24.830	24.709	520
530	25.702	25.581	25.460	25.339	25.218	25.097	24.976	24.855	24.734	24.613	24.492	530
540	25.485	25.364	25.243	25.122	25.001	24.880	24.759	24.638	24.517	24.396	24.275	540
550	25.268	25.147	25.026	24.905	24.784	24.663	24.542	24.421	24.300	24.179	24.058	550
560	25.051	24.930	24.809	24.688	24.567	24.446	24.325	24.204	24.083	23.962	23.841	560
570	24.834	24.713	24.592	24.471	24.350	24.229	24.108	23.987	23.866	23.745	23.624	570
580	24.617	24.496	24.375	24.254	24.133	24.012	23.891	23.770	23.649	23.528	23.407	580
590	24.400	24.279	24.158	24.037	23.916	23.795	23.674	23.553	23.432	23.311	23.190	590
600	24.183	24.062	23.941	23.820	23.699	23.578	23.457	23.336	23.215	23.094	22.973	600
610	23.966	23.845	23.724	23.603	23.482	23.361	23.240	23.119	22.998	22.877	22.756	610
620	23.749	23.628	23.507	23.386	23.265	23.144	23.023	22.902	22.781	22.660	22.539	620
630	23.532	23.411	23.290	23.169	23.048	22.927	22.806	22.685	22.564	22.443	22.322	630
640	23.315	23.194	23.073	22.952	22.831	22.710	22.589	22.468	22.347	22.226	22.105	640
650	23.098	22.977	22.856	22.735	22.614	22.493	22.372	22.251	22.130	22.009	21.888	650
660	22.881	22.760	22.639	22.518	22.397	22.276	22.155	22.034	21.913	21.792	21.671	660
670	22.664	22.543	22.422	22.301	22.180	22.059	21.938	21.817	21.696	21.575	21.454	670
680	22.447	22.326	22.205	22.084	21.963	21.842	21.721	21.600	21.479	21.358	21.237	680
690	22.230	22.109	21.988	21.867	21.746	21.625	21.504	21.383	21.262	21.141	21.020	690
700	22.013	21.892	21.771	21.650	21.529	21.408	21.287	21.166	21.045	20.924	20.803	700
710	21.796	21.675	21.554	21.433	21.312	21.191	21.070	20.949	20.828	20.707	20.586	710
720	21.579	21.458	21.337	21.216	21.095	20.974	20.853	20.732	20.611	20.490	20.369	720
730	21.362	21.241	21.120	20.999	20.878	20.757	20.636	20.515	20.394	20.273	20.152	730
740	21.145	21.024	20.903	20.782	20.661	20.540	20.419	20.298	20.177	20.056	19.935	740
750	20.928	20.807	20.686	20.565	20.444	20.323	20.202	20.081	19.960	19.839	19.718	750
760	20.711	20.590	20.469	20.348	20.227	20.106	19.985	19.864	19.743	19.622	19.501	760
770	20.494	20.373	20.252	20.131	20.010	19.889	19.768	19.647	19.526	19.405	19.284	770
780	20.277	20.156	20.035	19.914	19.793	19.672	19.551	19.430	19.309	19.188	19.067	780
790	20.060	19.939	19.818	19.697	19.576	19.455	19.334	19.213	19.092	18.971	18.850	790
800	19.843	19.722	19.601	19.480	19.359	19.238	19.117	18.996	18.875	18.754	18.633	800
810	19.626	19.505	19.384	19.263	19.142	19.021	18.900	18.779	18.658	18.537	18.416	810
820	19.409	19.288	19.167	19.046	18.925	18.804	18.683	18.562	18.441	18.320	18.199	820
830	19.192	19.071	18.950	18.829	18.708	18.587	18.466	18.345	18.224	18.103	17.982	830
840	18.975	18.854	18.733	18.612	18.491	18.370	18.249	18.128	18.007	17.886	17.765	840
850	18.758	18.637	18.516	18.395	18.274	18.153	18.032	17.911	17.790	17.669	17.548	850
860	18.541	18.420	18.299	18.178	18.057	17.936	17.815	17.694	17.573	17.452	17.331	860
870	18.324	18.203	18.082	17.961	17.840	17.719	17.598	17.477	17.356	17.235	17.114	870
880	18.107	17.986	17.865	17.744	17.623	17.502	17.381	17.260	17.139	17.018	16.897	880
890	17.890	17.769	17.648	17.527	17.406	17.285	17.164	17.043	16.922	16.801	16.680	890
900	17.673	17.552	17.431	17.310	17.189	17.068	16.947	16.826	16.705	16.584	16.463	900
910	17.456	17.335	17.214	17.093	16.972	16.851	16.730	16.609	16.488	16.367	16.246	910
920	17.239	17.118	16.997	16.876	16.755	16.634	16.513	16.392	16.271	16.150	16.029	920
930	17.022	16.901	16.780	16.659	16.538	16.417	16.296	16.175	16.054	15.933	15.812	930
940	16.805	16.684	16.563	16.442	16.321	16.200	16.079	15.958	15.837	15.716	15.595	940
950	16.588	16.467	16.346	16.225	16.104	15.983	15.862	15.741	15.620	15.499	15.378	950
960	16.371	16.250	16.129	16.008	15.887	15.766	15.645	15.524	15.403	15.282	15.161	960
970	16.154	16.033	15.912	15.791	15.670	15.549	15.428	15.307	15.186	15.065	14.944	970
980	15.937	15.816	15.695	15.574	15.453	15.332	15.211	15.090	14.969	14.848	14.727	980
990	15.720	15.599	15.478	15.357	15.236	15.115	14.994	14.873	14.752	14.631	14.510	990
1,000	15.503											1,000
DEG C	0	1	2	3	4	5	6	7	8	9	10	DEG C

Type N Thermocouples. Nicrosil/Nisil

Temperature in Degrees Celsius

NICROSIL/NISIL REFERENCE TABLE mV v Temperature.

°C	0	10	20	30	40	50	60	70	80	90	100
0	0·000	0·261	0·525	0·793	1·064	1·340	1·619	1·902	2·188	2·479	2·774
100	2·774	3·072	3·374	3·679	3·988	4·301	4·617	4·936	5·258	5·584	5·912
200	5·912	6·243	6·577	6·914	7·254	7·596	7·940	8·287	8·636	8·987	9·340
300	9·340	9·695	10·053	10·412	10·773	11·135	11·499	11·865	12·233	12·602	12·972
400	12·972	13·344	13·717	14·092	14·467	14·844	15·222	15·601	15·981	16·362	16·744
500	16·744	17·127	17·511	17·896	18·282	18·668	19·055	19·443	19·831	20·220	20·609
600	20·609	20·999	21·390	21·781	22·172	22·564	22·956	23·348	23·740	24·133	24·526
700	24·526	24·919	25·312	25·705	26·098	26·491	26·885	27·278	27·671	28·063	28·456
800	28·456	28·849	29·241	29·633	30·025	30·417	30·808	31·199	31·590	31·980	32·370
900	32·370	32·760	33·149	33·538	33·927	34·315	34·702	35·089	35·476	35·862	36·248
1000	36·248	36·633	37·018	37·403	37·786	38·169	38·552	38·934	39·316	39·696	40·076
1100	40·076	40·456	40·835	41·213	41·590	41·966	42·342	42·717	43·091	43·464	43·836
1200	43·836	44·207	44·578	44·947	45·315	45·682	46·048	46·413	46·777	47·140	47·502
1300	47·502										

Full Table to BS 4937:1986 Part 8
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