TE-8

TEMPERATURE

INPUT CONVERSION

(for use with the ADC-4, ADC-8, ADC-16 & AD-16)

(TECHNICAL REFERENCE)

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SPECIFICATIONS

TE-8 Terminal Block Size.....   2" by 3"

Temperature Inputs...........   8

Temperature Range............   -40 degrees to 146 degrees F (default temperature range)
-40 degrees to 212 degrees F (with 10 or 12 bit converter)
-67 degrees to 302 degrees F (with 10 or 12 bit converter and extended range sensors)

Power Requirements...........   Powered from the A/D card (20MA thru ribbon cable)

PARTS LIST

The following parts are part of the TE-8 temperature input conversion and should be included in the packaging when ordering the TE-8. IMPORTANT NOTE: The price of the TE-8 includes installation of these parts. If you ordered the A/D card with the TE-8, all the following components will be installed on PORT #1 of the ADC-8 or ADC-16 card (with the exception of the temperature sensors, 10K trimmers and the TE-8 terminal block). PORT #1 (inputs 1 thru 8) on the ADC-8 or ADC-16 will then be dedicated for use as temperature inputs only. The TE-8 will be installed on Port #2 if you specified when ordering. If you did not order the A/D card with the TE-8, then you must ship your A/D card to the address on the rear cover of this manual for free installation of the TE-8 components.

(8) Integrated Circuit Temperature Sensors   (2) 3K Ohm Resistors
                                                (1) 243 Ohm Resistor
(1) 1.24 volt Voltage Reference   (1) 392 Ohm Resistor
(10) .01 mf Filter Capacitors   (1) 500 Ohm Trimmer Potentiometer
(1) 470 mf Filter Capacitor   (1) TE-8 Terminal Block with (8) 1.8K Ohm Resistors &
(1) LM317 Adjustable Voltage Reference   (8) Zener Diodes

SET-UP AND TESTING

Please test all your hardware upon receiving your shipment and before installing the hardware inside your equipment (or enclosure) to assure that the hardware is functioning properly. You may test the ADC-4, ADC-8, ADC-16 or AD-16 temperature option as follows (IBM or compatible computer with a DOS or Windows operating system):

PLEASE NOTE: Your hardware has been carefully tested for proper operation just prior to shipment. If you follow the instructions listed below and are using a cable and power supply that we provided, you should have little difficulty utilizing your temperature interface.

(1) Connect the serial cable to the A/D card as shown in it's technical reference. If you did not order a serial cable with your A/D card, you may construct your own as shown in the technical reference for the A/D card. Plug the other end of the cable into the COM 1 port on your computer.

(2) Plug the PS-GP-1 power supply into a 120 VAC power source and connect to the (+) and (-) terminals on the A/D card (use caution...reversed polarity may cause damage). Be careful not to place the A/D card or associated hardware on a metal surface or damage could be caused as a result of a short circuit. Care should be taken to prevent any static discharge on the A/D card and associated circuits by touching a metal ground before handling the hardware. Do not place the hardware on an anti-static mat after power-up as most of these mats will conduct electricity.

(3) Connect the TE-8 terminal block to the #1 port (or port #2 for the ADC-4) and the RCT-8 to the #2 port. The ribbon cables should point up (see the A/D card's technical reference). Connect only the #1 temperature sensor to the TE-8 as shown on the next page in figure A (without 10K trimpot). PLEASE DO NOT CONNECT THE REMAINING SENSORS OR 10K TRIMPOT UNTIL YOU HAVE SUCCESSFULLY CONNECTED AND TESTED THE #1 SENSOR*. (use caution... reversing the (+) and (-) leads on the sensor will cause damage).   * see sensor installation page 3 & 4

(4) The A/D card should be set to 9,600 baud for 8 bit converters or 19,200 baud for 10 & 12 bit converters. Run setup.exe in the folder Windows Data Acquisition Program (on CD supplied). If prompted about an older file, keep your newer file. After the ADC-16 program is installed, open: ADC-16E.dat

(5) Your screen will show a row of 8 temperatures on the top, and a row of 8 analog inputs on the bottom. The top row represents the temperature inputs for port #1 and the bottom row represents the analog inputs for port #2 (the ADC-4 will show a row of 4 analog inputs (12 bit) on the top and a row of 8 temperatures on the bottom). The analog inputs will be fluctuating as a result of noise on the inputs (this is normal). Test the #1 temperature input first. The temperature reading should be within 20 degrees of room temperature with sensor connected. Place your thumb and forefinger around the temperature sensor. The temperature reading on your screen should increase (assuming that room temperature is less than about 85 degrees F). After you have successfully tested the #1 temperature input, connect the remaining sensors and repeat this test for each temperature input. All trim pots (if used) should be connected to the sensor within a half inch if possible (to reduce possible input noise). NOTE: When a temperature sensor is not connected to an input, that input will display 146 degrees or provide a blank indication. When a temperature input is shorted, that input will display -78 degrees (provided that the TE-8 ribbon cable is connected to the A/D card).

(6) To test the analog inputs, connect each input (one at a time) to the reference (-) terminal on the RCT-8 (see the A/D technical reference). Your screen should show a "0" for that input. After this is completed, connect each input (one at a time) to the reference (+) terminal on the RCT-8. Your screen should show a "255" with 8 bit inputs, "1023" with 10 bit inputs or "4095" with 12 bit inputs. When the inputs are left floating, random numbers will be displayed on the screen. Inputs which are not used should be connected to reference (-) with a jumper wire.

7) To exit the program, press any key. If you use ctrl break to stop the program, you may use CUR-ON.EXE to turn the cursor back on. If operation of the temperature and analog inputs are normal, then testing is now complete and the hardware may be placed in service. If problems are encountered during testing, proceed to the trouble-shooting procedures shown on the following page.

8 BIT A/D REFERENCE VOLTAGE ADJUSTMENT

The 500 Ohm trim pot on the top right side of the A/D card is adjusted for exactly 5.50 volts during testing prior to shipment of your order. Please test the temperature interface before adjusting the reference voltage. If adjustment is required, adjust the 500 ohm trim pot for exactly 5.50 volts (measure on the TE-8 terminal block across the sensor (-) common and reference (+) terminals (#9 and #10)). If this voltage is not adjusted for exactly 5.50 volts, the coefficients provided in the test software and in the examples will be inaccurate and the temperature range will be effected. NOTE: This adjustment is only required for 8 bit converters (10 and 12 bit converters do not have a 5.5 V reference).

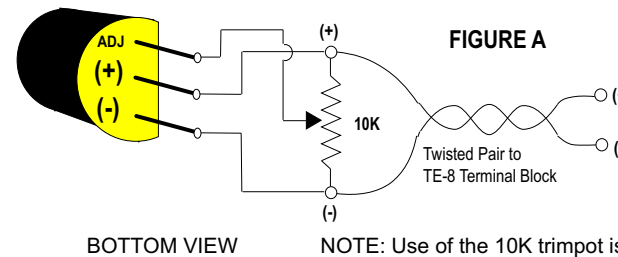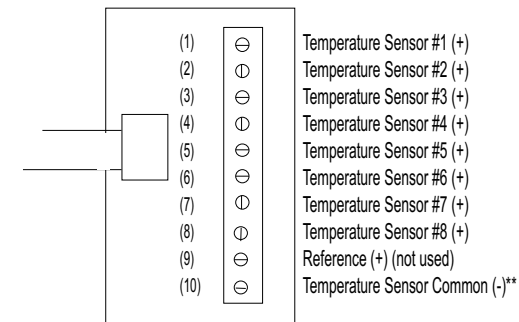## TE-8 TERMINAL BLOCK CONNECTIONS

(1)	⊖	Temperature Sensor #1 (+)
(2)	Ⓘ	Temperature Sensor #2 (+)
(3)	⊖	Temperature Sensor #3 (+)
(4)	Ⓘ	Temperature Sensor #4 (+)
(5)	⊖	Temperature Sensor #5 (+)
(6)	⊖	Temperature Sensor #6 (+)
(7)	Ⓘ	Temperature Sensor #7 (+)
(8)	Ⓘ	Temperature Sensor #8 (+)
(9)	⊖	Reference (+) (not used)
(10)	⊖	Temperature Sensor Common (-)**

TEMPERATURE SENSOR PIN-OUTS

TO-92 Plastic Package

TO-46 Metal Can Package

Bottom View

*Case is connected to negative pin

**Connect all 8 Sensor (-) here

FIGURE A

10K

Twisted Pair to TE-8 Terminal Block

BOTTOM VIEW

(ADJ)

10K TRIMMER

Bottom View

(-)   (+)

NOTE: Use of the 10K trimpot is optional (needed only if software does not calibrate) (leads should point toward you)

TROUBLE-SHOOTING

(1) Verify proper operation of the A/D card by running the test software and consulting the trouble-shooting section in the A/D technical reference.

(2) Check for the proper 8 bit A/D reference voltage on terminals 9 and 10 on the TE-8 terminal block (the reference (+) and temperature sensor (-)). The voltage should read exactly 5.50 volts DC (8 bit converters only). Check for 5 volts DC on the 2200 mf capacitor on the A/D card (low voltage may indicate an overload).

(3) Check for proper connection of the TE-8 ribbon cable (connect the same way as the RCT-8 is attached as shown in the A/D technical reference). Check for tight connections at the terminal block (tug on each wire). Check for proper connection of the temperature sensor as shown above. NOTE: Reversed polarity of the temperature sensor may damage the sensor (replace the sensor with a good one to determine if the sensor has been damaged). Damaged sensors may result in fluctuating temperature values, temperature drift, reversed reading or other problems. The ADJ lead on the sensor must be completely cut off when the trim pot is omitted (to prevent noise input).

(4) A short circuit of the temperature sensor wire will result in a -78 degree F reading. An open circuit of the temperature sensor wire will result in a 146 degree F or blank reading (8 bit converters only). Check for possible short circuits on the TE-8 terminal block. A damaged temperature sensor may also cause inaccurate readings (check for about 2.96 volts across the sensor wire with the sensor at normal room temperature).

(5) The temperature readings displayed on your screen should be completely stable and should not fluctuate up or down (except for brief flutter that may occur when the sensor is near ambient during transition). If your temperature readings are not stable, the most likely source is excessive noise produced by your power supply (other sources of noise such as RF or EMI may also be a factor). Switching power supplies or poorly filtered power supplies are often the source of significant noise and result in widely fluctuating temperature readings. Your best course of action here is to replace the power supply with a low cost, unregulated 9 VDC wall transformer supply which may be purchased
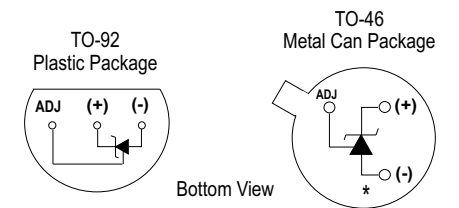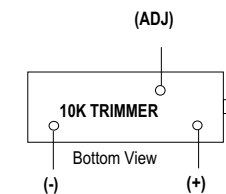
at most electronic shops. Use this wall transformer supply to power the A/D converter only (other devices connected to the power supply may also be a source of noise). Additional filtering of your power supply by adding a 4,700 microfarad parallel capacitor and a 10 ohm series resistance may reduce or eliminate the noise. External sources of noise such as utility company high voltage power transmission lines or radio/TV towers in the area may require shielding of all the hardware and of the temperature sensor wiring.

(6) If you are still unable to obtain the proper temperature readings when running the test software as described on page 2, please contact us at (937) 349-6000 for technical support.

NOTE: After power-up, the temperature sensors will generate several degrees of self heating. Allow at least a half an hour for the sensor to stabilize after power-up before adjusting the trimpots for sensor calibration.

TEMPERATURE SENSOR INSTALLATION

Communication wire or cable (22 or 24 gauge typical) may be used to connect the temperature sensors to the TE-8 as long as the pairs are twisted. If the temperature sensor is within 20 feet of the TE-8, the twisted pair may not be necessary but input noise may cause slight fluctuations in your temperature readings. If you are in an area that generates strong RF signals or EMI, you may have to use shielded cable (in addition to the twisted pair) to eliminate fluctuations caused by the noise on the inputs. Generally, twisted pair wire will be sufficient to cancel noise with distances up to several hundred feet from the TE-8. Connect one conductor of the twisted pair to the temperature input and the other conductor to the temperature sensor common (-). All eight of the temperature sensor (-) terminals will connect to the common (-) terminal on the TE-8. If shielded cable with twisted pair is used, connect the shield to an earth ground at the TE-8 and leave the shield disconnected at the temperature sensor. We recommend that any temperature inputs that are not used be connected to the reference (-) with a jumper wire.

The recommended temperature sensor cable is Beldon 8450 (22 ga twisted pair with shield) Industrial PVC

To determine a location for your temperature sensor, please observe the following precautions (this is especially important if you are controlling heating and air conditioning equipment with the temperature sensors):

   (1) Do not locate the temperature sensor on an outside wall or where the sensor will be in direct sunlight.

   (2) Do not locate the temperature sensor close to devices which produce heat (such as above a light dimmer).

   (3) Completely plug any holes in the wall near the temperature sensor with a foam type insulation (including the hole that your sensor wire passes through). The temperature of a small draft coming from inside the wall can greatly vary from actual room temperature.

   (4) Do not locate the temperature sensor close to heating or air conditioning return air or supply vents or in an area that normally experiences a lot of draft (such as near an outside door).

   (5) When installing a temperature sensor outdoors for measuring outside temperature, be sure to locate the sensor on a north or east wall that is well shielded from direct sunlight. The temperature sensor itself should have a shield over it to protect it from the weather and direct sunlight. A brick wall is normally not a good place for a temperature sensor because of the heat retaining effect of the brick. A light colored surface is desired when locating the sensor. A black surface will absorb the heat and result in inaccurate readings. A trim pot for an outdoor sensor is not recommended (a major temperature change of the trim pot can result in a change of resistance and result in an inaccurate temperature reading).

   (6) When the temperature sensor is to be submerged in water or exposed to humid conditions, completely coat the sensor leads, the trim pot and any exposed wire with a good quality epoxy.

   (7) The temperature sensor may be mounted to hot water pipes or refrigerant lines using tape or a small "tubing type" stainless steel clamp (do not over tighten). An insulating material should be taped over the sensor and clamp after installation.

CALIBRATION

 The solid state sensors are actually small integrated circuits which have been designed to provide a linear output of 10 millivolts per degree change in Celsius (or 5.5555 millivolts per degree Fahrenheit). The temperature sensor is calibrated by adjusting the 10K trim pot for 2.982 volts across the (+) and (-) terminals of the temperature sensor when the sensor is at 25 degrees Celsius (77 degrees F). The 2.982 volt adjustment will only be correct at 25 degrees Celsius (77 degrees Fahrenheit). When the temperature sensor is at a temperature higher or lower than 77 F, adjust the voltage to compensate for the temperature difference from the 77 F reference point. EXAMPLE: If the temperature sensor is at 67 degrees F adjust for a voltage of 2.927 volts... which is 2.982 volts minus the temperature difference of 10 degrees F (10 times 5.5555 millivolts). **NOTE:** Most HVAC applications do not use the 10K trimpot but instead use software calibration to prevent tampering and to simplify installation.

A simplified (but less accurate) method of calibrating the temperature sensor is to simply adjust software (or 10K trimpot) to read room temperature. When using this method to calibrate the temperature sensor, be sure that the room temperature is stable for at least 10 minutes before reading your thermometer (especially with mercury thermometers). The temperature sensors provided with the TE-8 are fast acting sensors and the lead or lag with other solid state sensors, thermistors or mercury thermometers may produce several degrees of error when the temperature is fluctuating (the normal cycling of heating and air conditioning equipment may produce 5 degrees or more of fluctuation).

Typical accuracy of the temperature sensor is normally within plus or minus 1 degree F over the temperature range of -40 F to 146 F (provided that the 10K trim pot does not introduce error as a result of temperature drift). To achieve maximum accuracy, the temperature sensor and trim pot should be allowed to acclimate to ambient temperature for several hours after the first adjustment and then re-adjusted to compensate for self-heating of the sensor and trim pot. Additional accuracy of the temperature sensor can be achieved by calibrating the sensor when the sensor's temperature is near the center of it's anticipated operating range. Other factors which may effect the accuracy of the temperature sensors include the environment in which the sensor trim pots and voltage reference are installed (including the voltage reference trim pot on the A/D card). A significant change of temperature of the A/D voltage reference and trim pots or physical vibration of the trim pots can effect reference voltage and result in error.

TRIMMER POTENTIOMETERS: The 10K trim pots which are provided are optional and do not have to be used if your application does not require a high degree of accuracy (the adjust lead should be clipped off to reduce noise). If the trim pots are omitted, each temperature sensor will have to be individually calibrated in software. Typical accuracy of the temperature sensor without a calibrated trim pot is normally within plus or minus 2 degrees F over the -40 F to 146 F temperature range. The advantage in using the 10K trim pots (in addition to greater accuracy) is that all the temperature sensors will require only one software subroutine to compute temperature. Another advantage is that if a sensor is replaced, that sensor can be individually calibrated without effecting software. Trim pots should be installed within a half inch of the temperature sensor if possible. The trim pots may be located further distances if needed but the wire should be shielded If the trim pots are omitted, the temperatures will read up to 20 degrees higher and will have to be compensated for in software. One disadvantage of using the trim pots is that the sensor is subject to tampering by unauthorized persons and/or the trim pot may be jarred out of adjustment by vibration and require periodic adjustment. The trim pot may also produce temperature errors if the trim pot is exposed to major changes in temperature.

INCREASING THE UPPER TEMPERATURE LIMIT

The upper limit of the temperature range can be increased from 146 degrees F to approximately 175 to 200 degrees F by adjusting the trim pot on the A/D card to a higher voltage. It will be necessary to decrease the temperature adjustment factor in your software to compensate for the difference. The 1.2 volt reference on the A/D card should be approximately centered about the A/D power supply voltage. When the trimmer on the A/D card is increased from 5.5 volts to a higher value, the 1.2 volt reference is swung increasingly off-center until somewhere around 6.25 volts the A/D conversions will abruptly stop. This threshold will vary depending on the characteristics of the A/D chip. If the higher limit is not needed, the A/D trim pot should be adjusted for 5.5 volts for greater temperature accuracy.

An alternate method for increasing the upper temperature limit is to order the ADC-16 with the /G or /H 10 bit option or to use the ADC-4 12 bit converter. The use of the 10 & 12 bit converters will allow measurement of temperatures as high as 212 F (standard sensors) or 302 F (extended range sensors).

TECHNICAL SUPPORT

Technical support for our products is available by calling (937) 349-6000. If a technical adviser is not available, please leave your name, phone number and a time that you can be reached. Your call will be returned as soon as possible and within 24 hours.

8 BIT CONTROL SOFTWARE

EXAMPLE PROGRAMS are on the test disk and are labeled TE-8.BAS for basic, TE-8.C for C and TE-8.ASM for assembly. Examples in Visual Basic are in the VB directory. You may use these programs as subroutines in your software or for development of your own software.

SOFTWARE DEVELOPMENT: If you are using Basic or C, you may use the test programs supplied with this literature as a guide when designing software for specific applications. The various coefficients are computed as follows:

FAHRENHEIT CONVERSION COEFFICIENT: To determine the proper software coefficient for Fahrenheit readings, first measure the voltage across the voltage reference inputs on the 28 pin 0809 chip for the temperature port (- reference is pin #16 and + reference is pin #12). Divide this voltage by 256 to determine the voltage per increment (AD resolution). EXAMPLE: if the voltage across pins #12 and #16 on the 0809 chip is 1.253 volts, divide 1.253 by 256 (1.253 / 256 = .00489 volts or 4.89 millivolts resolution). If you are using a 10 or 12 bit converter you will divide by 1,024 or 4,096 and you will use the reference voltage across terminals 9 & 10 on the TE-8 terminal block.

FAHRENHEIT CONVERSION COEFFICIENT = AD RESOLUTION / SENSOR RESOLUTION

The temperature sensor resolution will always be 5.5555 millivolts for Fahrenheit temperatures or 10 millivolts for Celsius or Kelvin temperatures. EXAMPLE: 4.89 / 5.55 = .88 the Fahrenheit coefficient for an AD resolution of 4.89 millivolts. (see line 190 in the Basic program)

CELSIUS CONVERSION COEFFICIENT = AD RESOLUTION / SENSOR RESOLUTION

EXAMPLE: 4.89 / 10 = .49 the Celsius coefficient.

TEMPERATURE ADJUSTMENT FACTOR: Since the A/D card can only transmit positive numbers, the TE-8 has been designed to add 78 degrees F to the analog signal so that temperatures as low as 78 degrees below zero can be transmitted. To compensate for the temperature adjustment factor, after the value transmitted by the A/D card is received, first multiply this value by the conversion coefficient and then subtract 78 to obtain the correct temperature (see line 190 in the Basic program on page 8). The temperature adjustment factor will be 78 only if the ADC-16 reference voltage is adjusted to exactly 5.50 volts and the 10K trim pots are installed and properly calibrated. If the trim pots are omitted, the temperature adjustment factor will vary, depending on the temperature sensor (approximately 95) and must be corrected by adding or subtracting to this value in software. The Celsius temperature adjustment factor is 61.1 with the correct software coefficient and trim pot adjustment. If you are using a 10 or 12 bit converter, the temperature adjustment factor will be different (see software example).

SOFTWARE EXAMPLES

Shown on the following pages or on disk are software examples in GW Basic, Quick Basic, Visual Basic, Turbo C and Turbo Assembly. The programs were tested on an IBM PC running DOS or Windows. The programs will display 8 temperature inputs and 8 analog inputs. The protocol is set as follows: 9600 baud, 8 data bits, 2 stop bits, and no parity. Program examples using a called subroutine will be listed with a "SR" suffix. The programs have an error trapping feature to prevent computer lock-up.

C PROGRAM EXAMPLE

```c
#include <conio.h>                        *IBM & COMPATIBLES
#include <dos.h>                          *TURBO C
#include <stdio.h>
#include <bios.h>

main()
{
int a, x, y, z, status, byte;             *DECLARE VARIABLES
{
union REGS regs;                          *TURN OFF CURSOR
regs.h.ah=1;
regs.h.ch=16;
regs.h.cl=0;
int86(0x10,&regs,&regs);
}
clrscr();
printf("               TE-8 TEST PROGRAM (9,600 baud, COM 1)");
outportb(0x3FB,128);   /* LINE CONTROL REGISTER, BAUD RATE LATCH ON */
outportb(0x3F8,12);    /* STORE BAUD RATE, LSB */
outportb(0x3F9,0);     /* STORE BAUD RATE, MSB  */
outportb(0x3FB,3);     /* BAUD RATE LATCH OFF  */
byte=inportb(0x3F8);                      *CLEAR COM BUFFER
while (bioskey(1)==0)                     *TERMINATE PROGRAM ON KEY PRESSED
  {
  gotoxy(1,3);                            *POSITION CURSOR
  byte=inportb(0x3F8);                    *CLEAR COM BUFFER
  for (x=0; x<=16; ++x)                   *CHANNEL CODES
   {
   if (x==8) z=0;
   else z=x;                              *SYNCHRONIZE
   if (x==16) z=15;                       *TRANSMIT LAST CODE TWICE
   outportb(0x3F8,z);                     *TRANSMIT BYTE
   y=0;                                   *CLEAR VARIABLE
   do
    {
    status=inportb(0x3FD);               *CHECK LINE STATUS REGISTER
    a=status & 1;                         *DATA READY BIT SET?
    y=y+1;                                *WAIT FOR BYTE IF NOT SET
    if (y>5000) a=1;                      *EXIT LOOP IF BYTE LOST
    }
   while (a==0);
   byte=inportb(0x3F8);                   *RECEIVE BYTE
   if (x>8) printf("%3d\n",byte);         *DISPLAY ANALOG DATA ON SCREEN
   if (x>0 && x<9) printf("%3.0f\n",((byte*.88)-78));   *COMPUTE TEMPERATURE & DISPLAY
   if (x==8) printf("\n");                *SPACE
   }
  }
{
union REGS regs;                          *TURN ON CURSOR
regs.h.ah=1;
regs.h.ch=9;
```

```
regs.h.cl=10;
int86(0x10,&regs,&regs);
}
clrscr();                              *CLEAR SCREEN
x=bioskey(0);                          *CLEAR KEYBOARD BUFFER
}
```

*remarks only, do not include in program   NOTE: Updated programs will be on the test disk!

GW BASIC OR QUICKBASIC PROGRAM EXAMPLE

```
10 CLS
20 DIM A$(20)                          :'declare array
30 ON ERROR GOTO 240                   :'re-start on error
40 OPEN "COM1:9600,N,8,2,DS,CD,CS" AS #1    :'set protocol
50 FOR X= 0 TO 16                      :'channel codes
60 IF X=8 THEN Z=0:GOTO 90             :'synchronize
70 IF X=16 THEN Z =15:GOTO 90          :'transmit last code twice
80 Z=X
90 PRINT #1,CHR$(Z);                   :'transmit
100 IF Y>5000 THEN 140                 :'re-try on error
110 IF EOF(1) = -1 THEN Y=Y+1:GOTO 100 :'wait for byte
120 A$(X) = INPUT$(1,1)                :'receive
130 NEXT X
140 Y=0
150 IF EOF(1) = -1 THEN 170            :'check for error
160 A$ = INPUT$(1,1):CLOSE #1:GOTO 40  :'clear error (in COM buffer)
170 LOCATE 1,1
180 FOR X=1 TO 16
190 IF X<9 THEN PRINT INT(ASC(A$(X))*.88-78);"   "    :'compute temperature & display on screen
200 IF X>8 THEN PRINT ASC(A$(X));"  "  :'display analog inputs
210 IF X=8 THEN PRINT ""
220 NEXT X
230 GOTO 50                            :'repeat
240 RESUME                             :'start over if error (error subroutine can go here)
```

Additional information on software may be found in the technical reference for the A/D card.

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