KineticSystems Corporation

Model 3525-A1E

16-Channel Temperature Monitor

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*** SPECIAL NOTICE ***

EXTENDED RANGE FOR S, R, C, B TYPE THERMOCOUPLES

The range for S, R, C, and B type thermocouples has been extended to the thermocouple limits. All negative ranges will be read as zero. Accuracy is $\pm 2^{o}$C for the entire range.

New thermocouple ranges are listed:

- C type T/C (0 to 2308^{o}C)
- S type T/C (0 to 1768^{o}C)
- R type T/C (0 to 1768^{o}C)
- B type T/C (0 to 1820^{o}C)

This external range was accomplished by using the fifteenth bit (in our data format) as a data bit instead of a sign bit. Therefore, all high and low limits should be set with this in mind.

3 December 1984
PLM:sle

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KineticSystems Corporation

Standardized Data Acquisition and Control Systems

3525

16-Channel Temperature Monitor

May 78
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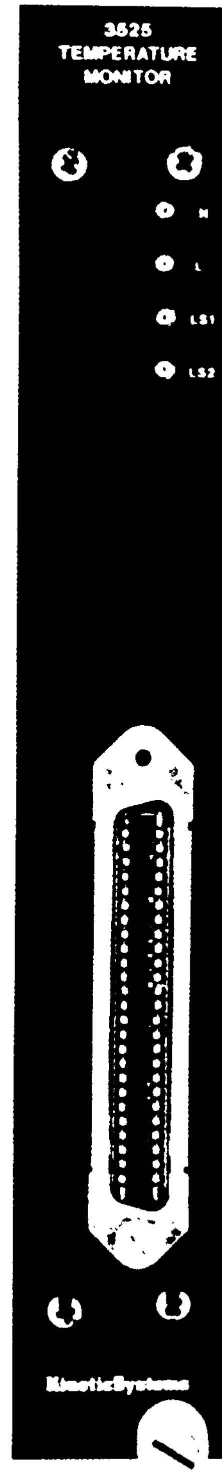

FEATURES

- ON-BOARD MICROPROCESSOR CONTROL
- 16 CHANNELS OF DIFFERENTIAL INPUTS WITH GUARD PER CHANNEL
- READOUT VIA DATAWAY DIRECTLY IN DEGREES CELSIUS OR FAHRENHEIT
- RESOLUTION OF 0.1°C.
- ACCURACY OF ±0.5°C. (EXCLUDING THERMOCOUPLE)
- OPTIONAL LINEARIZATION FOR TYPE B, C, E, J, K, CH-AU, R, S OR T THERMOCOUPLES
- CAN BE USED AS GENERAL-PURPOSE LOW-LEVEL MONITOR WITHOUT LINEARIZATION
- UPPER AND LOWER ALARM LIMITS FOR EACH CHANNEL WRITTEN AND READ FROM DATAWAY
- LAM INTERRUPT ON OUT-OF-LIMIT TEMPERATURE

APPLICATIONS

- DISTRIBUTED TEMPERATURE MONITORING SYSTEM
- HIGH ACCURACY TEMPERATURE CONTROL SYSTEM
- LOW-LEVEL HIGH-ACCURACY A/D CONVERTER

GENERAL DESCRIPTION

The Model 3525 16-Channel Temperature Monitor is a double-width CAMAC module which provides the user with the hardware and software necessary for converting thermocouple inputs to temperatures in degrees C. or degrees F. The module contains an on-board 8085 Microprocessor and a PROM specially programmed for the type of linearization required.

The 3525 accepts 16 different inputs; each also contains a guard. These inputs are scanned using low-thermal-EMF relays. The module also contains a differential pair and guard for a reference junction when the inputs come from an isothermal panel. A P.C. board strap selects whether the reference junction is internal or external.

All status registers can be read from the Dataway and a logical "1" means a channel is out of limit. LAM interrupts are set either by a channel exceeding its upper limit or by any channel going below its lower limit.

The temperature for each input is read from the Dataway. The data storage allows for a reading in the range of ±1638.3 degrees with a resolution of ±0.1°. The actual temperature range depends upon the thermocouple used. The reading is accurate to ±0.5°C, excluding the thermocouple tolerance. A strap on the module selects whether the value read is in degrees Celsius or degrees Fahrenheit. An on-board switch selects the last channel to be scanned. Each channel is scanned every 2800 msec (if all 16 channels are scanned). The scan time between channels is 175 msec.

Each 3525 channel contains an upper and lower limit register which can be written and read from the Dataway. Three registers set the maximum and minimum points (in increments of 0.1°C.or 0.1°F.) that each input must not exceed. The fifteenth bit in this register is the sign bit ("1" for negative) and the sixteenth bit is used by the processor to ignore this particular limit (1" means ignore this limit). The module contains four status registers. These status registers provide the following information:

Reg. 1. Indicates those inputs that are above their upper limit.
Reg. 2. Indicates those inputs that are below their lower limit.
Reg. 3. Indicates those inputs that have exceeded their upper limit since they were last read.
Reg. 4. Indicates those inputs that have exceeded their lower limit since they were last read.

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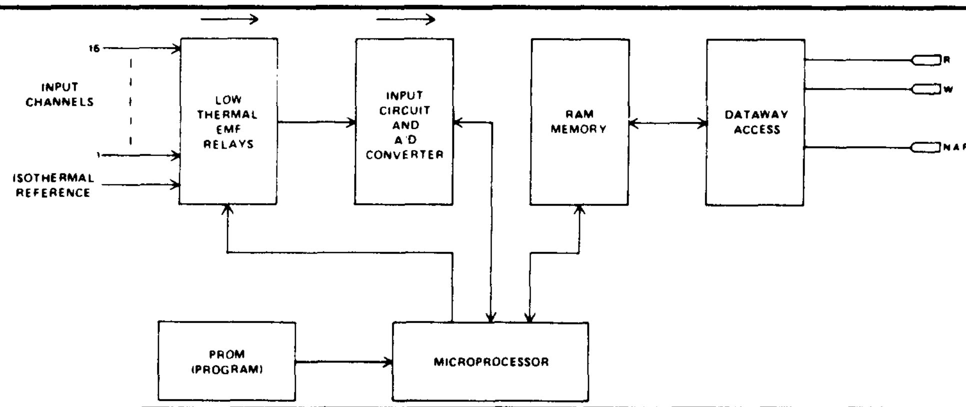
FUNCTION CODES

Command		Q	Action
F(0)·A(0)-A(15)	RD1	1	Read data out of selected channel.
F(1)·A(0)	RD2	1	Read status register for upper limit.
F(1)·A(1)	RD2	1	Read status register for lower limit.
F(2)·A(0)	RC1	1	Read and clear flag register for upper limit.
F(2)·A(1)	RC1	1	Read and clear flag register for lower limit.
F(4)·A(0)-A(15)	F04	1	Read lower temperature limit of selected channel.
F(6)·A(0)-A(15)	F06	1	Read upper temperature limit of selected channel.
F(8)·A(0)	TLM	LRL	Tests if lower limit LAM request is present.
F(8)·A(1)	TLM	LRU	Tests if upper limit LAM request is present.
F(8)·A(15)	TLM	LR	Tests if LAM is present.
F(10)·A(0)	CLM	1	Clears lower limit LAM status.
F(10)·A(1)	CLM	1	Clears upper limit LAM status.
F(20)·A(0)-A(15)	F20	1	Writes lower limit of selected channel.
F(22)·A(0)-A(15)	F22	1	Writes upper limit of selected channel.
F(24)·A(0)	DIS	1	Disables lower limit LAM request.
F(24)·A(1)	DIS	1	Disables upper limit LAM request.
F(26)·A(0)	ENB	1	Enables lower limit LAM request.
F(26)·A(1)	ENB	1	Enables upper limit LAM request.
F(27)·A(0)	TST	LSL	Tests lower limit LAM status.
F(27)·A(1)	TST	LSU	Tests upper limit LAM status.
Z	CZ	0	Disables LAM requests and resets microprocessor.

Note: X = 1 for all valid addressed commands.

SIMPLIFIED BLOCK DIAGRAM



POWER REQUIREMENTS:
+6 volts – 1050 mA
–6 volts – 15 mA
+24 volts – 55 mA
–24 volts – 15 mA

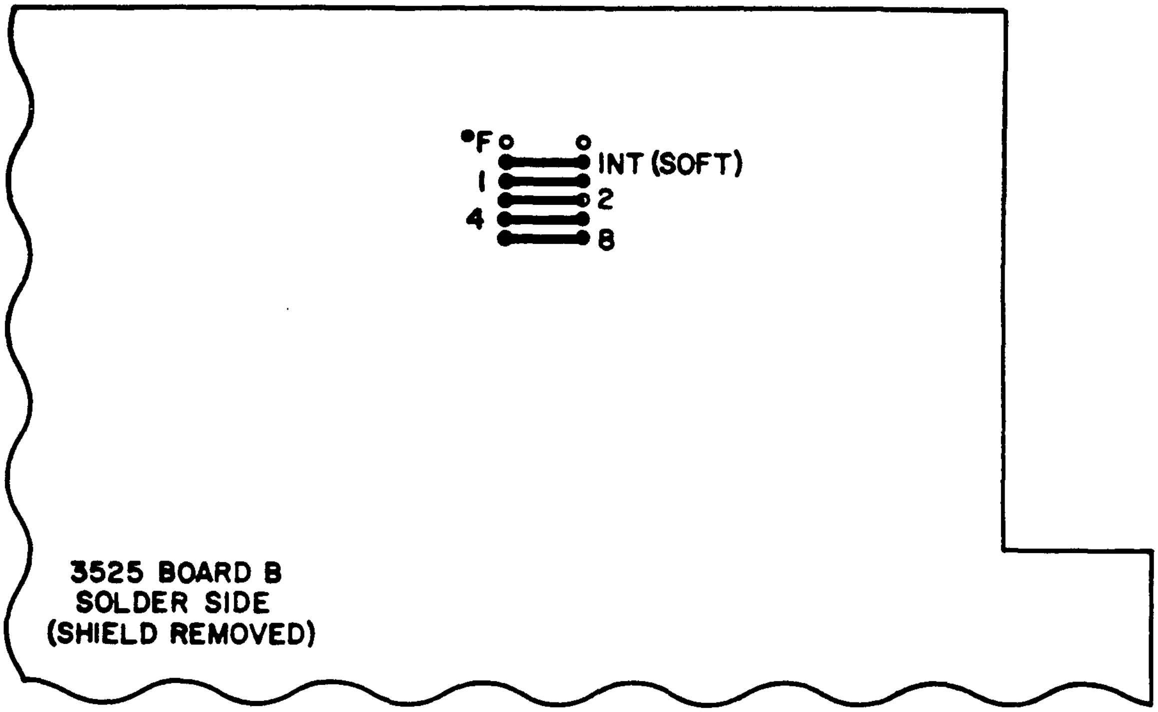
ORDERING INFORMATION

Weight: 1.25 kg. (2 lb. 12 oz.)

Model 3525-A1A – Low-level A/D (0 to 51.2 mV)
Model 3525-A1B – Type B Thermocouples
Model 3525-A1C – Type C Thermocouples
Model 3525-A1E – Type E Thermocouples
Model 3525-A1J – Type J Thermocouples
Model 3525-A1K – Type K Thermocouples
Model 3525-A1L – Type CH-AU Thermocouples
Model 3525-A1R – Type R Thermocouples
Model 3525-A1S – Type S Thermocouples
Model 3525-A1T – Type T Thermocouples

Accessories – Model 1991 Isothermal Panel

STRAP OPTIONS



There are three strap options on the 3525: °F, software compensated (SOFT), and LAST CHANNEL READ.

If temperature readout in °F is desired, install a strap at the °F location; otherwise the reading is in °C. This strap can be checked from the Dataway by doing any F(0). Bit 24 indicates if the °F strap is installed (logical 1).

Normally the SOFT strap is installed. This tells the 3525 that the T/C reference junction temperature is compensated for in software. (See Thermocouple Reference Junction Information.)

The strap is removed when the inputs are already compensated. This would be the case when the T/C to copper junctions are referenced to the ice point of water. This can be done by physically placing the junctions in an ice bath or electronically by using a junction compensator such as the Omega CJ.

When using the KSC Model 1990 Isothermal Panel, the SOFT strap is installed. (See Thermocouple Reference Junction Information.)

The LAST CHANNEL READ option allows the user to determine the number of channels read. For example, if only channels 0-3 are being used, straps in locations 1 and 2 will indicate that channel 3 is the last channel to be scanned. This way, unused channels 4-15 are not scanned, allowing faster update of channels 0-3.

SCAN TIME

Conversion time is approximately 175 milliseconds per channel.

If all 16 channels are scanned, update time is 2.8 seconds.

REGISTER DESCRIPTIONS

The 3525 contains four main registers. Each type is described below.

Temperature Limit Registers (TL)

These registers are written by the user to specify the upper and lower temperature limits for each channel. If the limit feature is not used, an ignore bit can be set. This tells the internal microprocessor to ignore that particular limit. These registers can also be read from the Dataway. There are 32 TL registers.

Data Format

Bit	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	MSB															LSB

Bits 14 – 1: Temperature limit in tenths of a degree

Bit 15: Sign bit 1 - negative
0 - positive

Bit 16: Limit ignore bit 1 - ignore limit
0 - include limit

	Upper Limits (16)	Lower Limits (16)
Write	F(22)·A(0) - A(15)	F(20)·A(0) - A(15)
Read	F(6)·A(0) - A(15)	F(4)·A(0) - A(15)

<u>Note:</u> The limit registers for channel 0 are written and read at subaddress A(0), channel 1 at A(1), etc.

Flag Registers (F)

These registers indicate which channels have gone out of limit. If a channel exceeds a limit and then comes back within that limit, the flag bit will remain set (logical 1). This is an indication that that channel has gone out of limit at some time since this register was last read. After each F register read, all flags in that register are set to logical 0 (read and clear operation). There are two F registers, and each register can only be read from the Dataway.

Data Format

Channel #	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	MSB															LSB

1 - This channel has gone out of limit since last read operation.
0 - This channel has not gone out of limit since last read operation.

Upper Limit	Lower Limit	Read and clear
F(2)·A(0)	F(2)·A(1)	

Status Registers (S)

These registers show which channels are currently out of limit. Each bit (1-16) is updated as that channel is scanned. These registers can only be read from the Dataway. There are two S registers.

Data Format

Channel #	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	MSB															LSB

1 - This channel out of limit.
0 - This channel within limit.

Upper Limit	Lower Limit	Read only
F(1)·A(0)	F(1)·A(1)	

Temperature Data Registers (TD)

These registers contain temperature data from each channel. The temperature is read directly in tenths of a degree. The MSB is the out of limit bit. TD registers are read only. There are 16 TD registers.

Data Format

Data bit	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	MSB															LSB

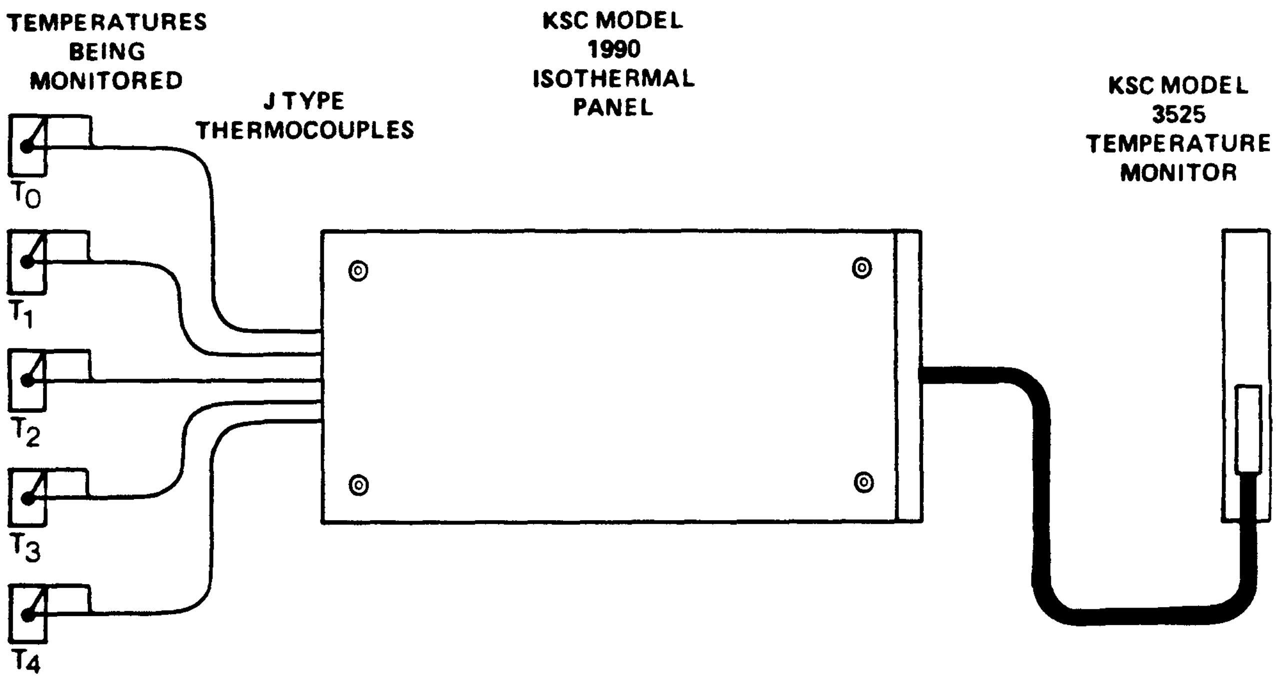
- Temperature in tenths of a degree (bits 14–1)
- Sign bit 1 - negative, 0 - positive (bit 15)
- Limit bit 1 - out of limit, 0 - within limit (bit 16)

F(0)·A(0) - A(15) Read only

Note: The temperature data register for channel 0 is read at subaddress A(0), channel 1 at A(1), etc.

OPERATION EXAMPLES

System configuration: In the following examples, our temperature monitoring system will be configured as shown in Figure 1.



Initial Setup and Strap Options

T_0 - T_4 are temperatures being monitored by the 3525. We will assume J type thermocouples are being used. T_0 - T_4 will correspond to channels 0-4. Since channel 4 is the last channel read, the 3525 would be strapped for the last channel read = 4. We will work in $^{\circ}C$ so there is no strap in the $^{\circ}F$ location. Because we are using the Model 1990 Isothermal Panel, the SOFT strap is installed.

LAMs and Limits

Upon power-up, the 3525 will immediately begin scanning channels 0-4. Since no limits have been specified, random limits will be present. This may cause LS1 or LS2 to be true. (LAM requests are disabled at power-up.)

Setting limits: In Figure 1, T_3 and T_4 are critical temperatures. These points must be in the range of -10.0°C to +95.0°C. Limits are of no concern on T_0 - T_2. We would therefore do the following:

	Command	Action
F(22)·A(0)	Data = 8000H (100000 octal)	Ignore upper limit on channels
F(22)·A(1)	Data = 8000H (100000 octal)	0 - 2.
F(22)·A(2)	Data = 8000H (100000 octal)	
F(20)·A(0)	Data = 8000H (100000 octal)	Ignore lower limit on channels
F(20)·A(1)	Data = 8000H (100000 octal)	0 - 2.
F(20)·A(2)	Data = 8000H (100000 octal)	
F(22)·A(3)	Data = 03B6H (1666 octal)	Include limit of +95.0°C
F(22)·A(4)	Data = 03B6H (1666 octal)	on channels 3 and 4.
F(20)·A(3)	Data = 4064H (40144 octal)	Include limit of -10.0°C
F(20)·A(4)	Data = 4064H (40144 octal)	on channels 3 and 4.

If no limits are being used on any channel, it is not necessary to set all "ignore" bits. In this case though, LS1 and LS2 may be set.

If limits are being used, all scanned channels should have limits set or the "ignore" bit set.

We will also enable the upper and lower limit LAM request. In this way, a LAM interrupt will occur if T_3 or T_4 goes out of limit.

To clear LS1 and/or LS2, which may have been set before limits were written, we would do the following:

F(10)·A(0)	Clears LS1
F(10)·A(1)	Clears LS2

And then we enable the LAM requests:

F(26)·A(0)	Enables lower limit LAM request.
F(26)·A(1)	Enables upper limit LAM request.

Now we are ready to begin monitoring temperatures.

To read T_0 we do an F(0)·A(0). Data returned = 00DEH (336 octal) which corresponds to 22.2°C.

To read T_1, we do an F(0)·A(1). Data returned = 40AAH (40252 octal) which is -17.0°C.

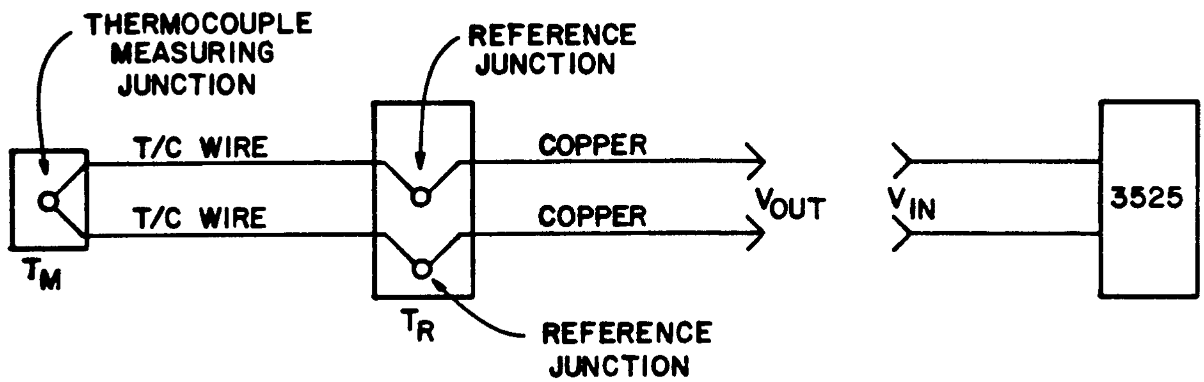
Let us assume that a LAM interrupt occurs in our system. Reading the LAM pattern in the crate controller will tell us if it was the 3525 that set the LAM.

Note: If this is an interrupt-driven system (as indicated), we would not need the F(8)·A(15) as part of the routine. The L pattern in the crate controller tells us which module contains the L.

Doing an F(8)·A(0) and F(8)·A(1) will determine if it was a lower limit or an upper limit that set the LAM. If the F(8)·A(1) returns Q=1, then it was an upper limit that was exceeded. Doing an F(1)·A(0) will tell us which channel has exceeded its limit. Assume that data returned was 8H (10 octal). This tells us that channel 3 has exceeded its limit.

Reading channel 3 [F(0)·A(3) Data returned = 8368H (101550 octal)], we find that it is still out of limit and that the temperature is +95.2°C.

THERMOCOUPLE REFERENCE JUNCTION INFORMATION



T_M = Temperature being measured

T_R = Temperature reference

The actual voltage created at the input to the 3525 is a function of the difference between the temperature being measured and the reference temperature. In mathematical terms $V_{in} = f(T_M - T_R)$.

In the diagram shown above using a pair of T/C wire, if T_R is held at a fixed known temperature, then V_{in} is a function only of the temperture being measured. If the reference junctions are maintained at T_R=0°C, then V_{out} would be dependent only on T_M. $(T_M - 0^oC) = T_M$.

In the case where T_R is some other <u>fixed</u> known temperature, the voltage at V_{out} would be offset by an amount proportional to that temperature. (This temperature would have to be included in the 3525 software to compensate for the offset introduced).

If the KSC Model 1990 is used with the 3525, T_R is the temperature of the 1990. Even though this temperature is not fixed, it is monitored by the 3525 and can then be used to compensate for the offset introduced by T_R. The advantage to using the 1990 is that it does not require any power. The other methods described above require some external power source to maintain T_R at a constant temperature.

An electronic compensation circuit can be made to directly subtract the offset error when T_R is not fixed. This is usually done with a bridge network in which one leg of the bridge contains a temperature (T_R) sensitive resistance element. In this way, the bridge circuit electrically compensates for the reference junctions not being at 0^oC.

A/D SPECIFICATIONS (25°C)

Resolution	13 bits (two's complement)
Relative accuracy	±1/2 LSB
Gain error	±1/2 LSB
Gain error drift	1 ppm/°C
Offset error	±1/2 LSB
Offset error drift	1 ppm/°C

AMPLIFIER SPECIFICATIONS

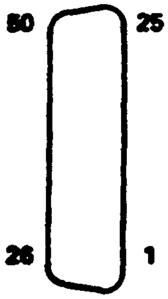
Maximum gain nonlinearity vs. temperature	.006% 5 ppm/°C	(G = 110)
Voltage offset RTI vs. temperature	<3μV/°C	
Differential input impedance	10^9 ohms	
Maximum differential input	±20 volts	
Maximum common mode input	±15 volts	
CMRR (DC to 3 Hz)	110 dB	

MODULE INPUT SPECIFICATIONS

Protection

Maximum differential input	±18 volts	
Maximum common mode input	±9 volts continuous	(45 volts for 1/120 second)
Input impedance	270 kiloohms	
Offset Drift	None (Auto zero)	
Gain Drift	<10 ppm	

Model
3525



FACE VIEW

Socket/Wire List

50 SOCKET RIBBON CONN.

SOCKET NO.		SOCKET NO.	
50	AD 590 (-)	25	AD590 (+)
49	Channel 15 Low (-)	24	Channel 15 High (+)
48	Channel 14 Guard (S)	23	Channel 15 Guard (S)
47	Channel 14 Low (-)	22	Channel 14 High (+)
46	Channel 13 Low (-)	21	Channel 13 High (+)
45	Channel 12 Guard (S)	20	Channel 13 Guard (S)
44	Channel 12 Low (-)	19	Channel 12 High (+)
43	Channel 11 Low (-)	18	Channel 11 High (+)
42	Channel 10 Guard (S)	17	Channel 11 Guard (S)
41	Channel 10 Low (-)	16	Channel 10 High (+)
40	Channel 9 Low (-)	15	Channel 9 High (+)
39	Channel 8 Guard (S)	14	Channel 9 Guard (S)
38	Channel 8 Low (-)	13	Channel 8 High (+)
37	Channel 7 Low (-)	12	Channel 7 High (+)
36	Channel 6 Guard (S)	11	Channel 7 Guard (S)
35	Channel 6 Low (-)	10	Channel 6 High (+)
34	Channel 5 Low (-)	9	Channel 5 High (+)
33	Channel 4 Guard (S)	8	Channel 5 Guard (S)
32	Channel 4 Low (-)	7	Channel 4 High (+)
31	Channel 3 Low (-)	6	Channel 3 High (+)
30	Channel 2 Guard (S)	5	Channel 3 Guard (S)
29	Channel 2 Low (-)	4	Channel 2 High (+)
28	Channel 1 Low (-)	3	Channel 1 High (+)
27	Channel 0 Guard (S)	2	Channel 1 Guard (S)
26	Channel 0 Low (-)	1	Channel 0 High (+)

Calibration procedure for 3525 Temperature Module

<u>NOTE:</u> If module option if a 3525 A1R, A1S, or an A1T test the module as an A1K first, then as the other option.

1. Put the "B" board on the extender.
2. Using IC clip, connect E-10 to E-16.
3. Turn Power on.
4. Using the DVM, Monitor the voltage (to the nearest millivolt) between P-3 and P-8 (ground). It should be very close to 10.000 volts.
5. Monitor the voltage between P-7 and P-8 (ground) and adjust the 5KΩ Vishay (see fig. 1) pot, until the voltage reads exactly half of the voltage as recorded in Step 4. It should be very near 5.000 volts. Notice that chip P is keyed with Pin 1 down.
6. Remove the test clip from chip E.
7. Power down.
8. Using the IC clip, connect U-1 to U-8.
9. Monitor the voltage between P-5 and P-8 (ground).
10. Power up.
11. Set the Biddle box for 0.000mV.
12. Using the 3525 connector, connect the Biddle box to pins 26(-) and 1(+).
13. Adjust the amplifier offset pot (see fig. 1) until the output of the amplifier reads 0.000000 volts.
14. Set the Biddle box for $V_{T\ MAX}$. (51.2mV for all options).
15. Adjust amplifier gain pot (see fig. 1) until the output of the amplifier reads 4.705882 volts, +/-500µv.
16. Remove IC clip from chip U.
17. Power down.
18. Put "A" board on an extender.
19. Put "B" board on an extender next to the "A" board and connect the ribbon cables.
20. Remove the SOFT strap on the "B" board.
21. Power up.
22. Verify that the LS1 and/or LS2 LEDS on the "B" board come on when powered up.
23. Using the 3525 connector, connect the Biddle box to pins 26(-) and 1(+).
24. Set the Biddle box for 0mV. Set TSTCAMAC to loop on F(0) A(0) and read back in decimal. It is also necessary to give the 3525 an F(20) A(0) D(8000h), and an F(22) A(0) D(8000h) to force it to disable upper and lower limits.

25. The module should read back 0° +/-2°C, the maximum variance allowed. The module reads back in 1/10 volts. The original Kinetic Systems procedure calls for adjusting the amplifier offset pot if necessary, but this will not work.

26. Set the Biddle box to output 50mV, which is just below the maximum temperature for most ranges. Compare the readback with the chart for the type of thermocouple the PROM is set up for (A, B, E, J, K, etc). The original Kinetic Systems procedure calls for adjusting the amplifier gain pot if necessary, but this should not be necessary if Step 15 was done properly.

27. Once the temperatures are verified, set the Biddle box back to 0 volts. Increment the temperatures, using the thermocouple chart, by 1°C up to 10°C. Next, increment the temperature by 10°C up to 100°C. Then increment the temperature by 100°C up to the V_{TMAX}, which is 50mV.

28. Next, output the Biddle box to all channels, set it for 0V, and read all 16 channels.

29. Set the Biddle box for a midrange temperature, and read all 16 channels.

30. Set the Biddle box for V_{TMAX}, and read all 16 channels.

31. Insert the SOFT strap and hook up the 3525 to a Model 1990 or 1991 isothermal panel. Hook up the Biddle box directly to the 3525, NOT through the panel. The Biddle box has internal temperature compensation. This test requires that you measure the temperatures both at the isothermal panel, and inside the Biddle box. Place an accurate thermometer in the isothermal panel, right next to the AD590 temperature transducer. Record the reading, and make sure the temperature doesn't vary during the calibration procedure. Set the input switch of the Biddle box to Channel B, and short the terminals on Channel B. Set the switch for "Measure". Set the Biddle box switch to match the thermocouple type of the 3525 PROM. The Biddle box will display its own internal temperature. Record this reading, and keep checking periodically to make sure that it doesn't change during the calibration procedure. Take this temperature and subtract the isothermal panel temperature from it. This is the difference number, and it's the number that you have to add to all your readings from the 3525.

32. Set the Biddle box to the difference number described in Step 31. It should be a few degrees higher then 0°C. Adjust the compensation offset pot (see fig. 1) to read 0°C. from the 3525.

33. Adjust the Biddle box to a temperature that is just under the maximum temperature for the range set by the PROM. It should be near 50mV. Adjust the compensation gain pot (see fig. 1) so that the 3525 reads that temperature minus the difference temperature described in Step 31.

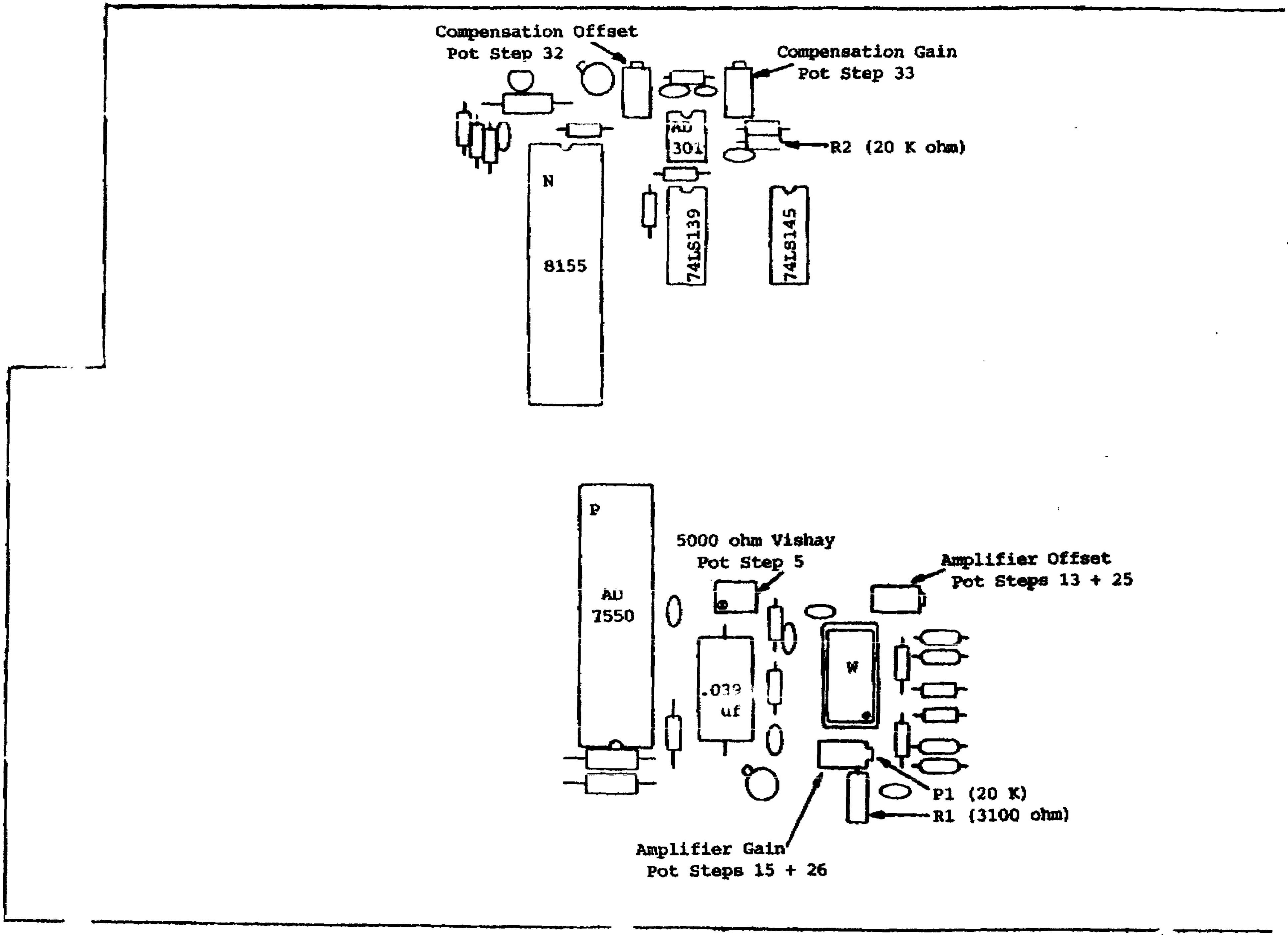
34. Repeat Steps 28-30, with temperatures (instead of voltages), keeping in mind that you have to compensate for the difference temperature described in Step 31.

35. Install the strap in °F (right above the SOFT strap). Set the Biddle box for the difference temperature described in Step 31. Make sure you read 32°F. Some PROM versions do not do the °F conversion properly.

36. Remove the °F strap, and put the module back together.

37. Run the module overnight in the crate and verify that it still works the next day by inputting a few temperatures and verifying them. Always make sure that you compensate for the difference temperature described in Step 31. You may need to recalculate it, as the temperatures may have changed overnight.

3525 B BOARD FIGURE 1.



KSC

3525

TABLE 1

Thermo-couple Type	V_T MAX (Millivolts)	Temp. °C	DATA		
			Decimal	Hex	Octal
A	51.20		5120	1400	12000
B					
E	51.20	676	6760	1A68	15150
J	51.20	760	7600	1DB0	16660
K	51.20	1265	12650	316A	30552
R	51.20				
S	51.20				
T	51.20	400	4000	FA0	7640

MAXIMUM TEMPERATURE RANGE

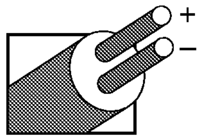
Thermocouple Grade
– 328 to 1652°F
– 200 to 900°C

Extension Grade
32 to 392°F
0 to 200°C

LIMITS OF ERROR
(whichever is greater)
Standard: 1.7°C or 0.5% Above 0°C
1.7°C or 1.0% Below 0°C
Special: 1.0°C or 0.4%

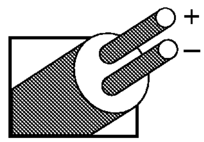
COMMENTS, BARE WIRE ENVIRONMENT:
Oxidizing or Inert; Limited Use in Vacuum or Reducing; Highest EMF Change per Degree

TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

Nickel-Chromium vs. Copper-Nickel



Extension Grade

Revised Thermocouple Reference Tables

TYPE E

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Z

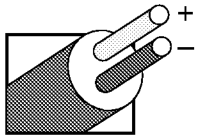
Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-260	-9.835	-9.833	-9.831	-9.828	-9.825	-9.821	-9.817	-9.813	-9.808	-9.802	-9.797	-260
-250	-9.797	-9.790	-9.784	-9.777	-9.770	-9.762	-9.754	-9.746	-9.737	-9.728	-9.718	-250
-240	-9.718	-9.709	-9.698	-9.688	-9.677	-9.666	-9.654	-9.642	-9.630	-9.617	-9.604	-240
-230	-9.604	-9.591	-9.577	-9.563	-9.548	-9.534	-9.519	-9.503	-9.487	-9.471	-9.455	-230
-220	-9.455	-9.438	-9.421	-9.404	-9.386	-9.368	-9.350	-9.331	-9.313	-9.293	-9.274	-220
-210	-9.274	-9.254	-9.234	-9.214	-9.193	-9.172	-9.151	-9.129	-9.107	-9.085	-9.063	-210
-200	-9.063	-9.040	-9.017	-8.994	-8.971	-8.947	-8.923	-8.899	-8.874	-8.850	-8.825	-200
-190	-8.825	-8.799	-8.774	-8.748	-8.722	-8.696	-8.669	-8.643	-8.616	-8.588	-8.561	-190
-180	-8.561	-8.533	-8.505	-8.477	-8.449	-8.420	-8.391	-8.362	-8.333	-8.303	-8.273	-180
-170	-8.273	-8.243	-8.213	-8.183	-8.152	-8.121	-8.090	-8.059	-8.027	-7.995	-7.963	-170
-160	-7.963	-7.931	-7.899	-7.866	-7.833	-7.800	-7.767	-7.733	-7.700	-7.666	-7.632	-160
-150	-7.632	-7.597	-7.563	-7.528	-7.493	-7.458	-7.423	-7.387	-7.351	-7.315	-7.279	-150
-140	-7.279	-7.243	-7.206	-7.170	-7.133	-7.096	-7.058	-7.021	-6.983	-6.945	-6.907	-140
-130	-6.907	-6.869	-6.831	-6.792	-6.753	-6.714	-6.675	-6.636	-6.596	-6.556	-6.516	-130
-120	-6.516	-6.476	-6.436	-6.396	-6.355	-6.314	-6.273	-6.232	-6.191	-6.149	-6.107	-120
-110	-6.107	-6.065	-6.023	-5.981	-5.939	-5.896	-5.853	-5.810	-5.767	-5.724	-5.681	-110
-100	-5.681	-5.637	-5.593	-5.549	-5.505	-5.461	-5.417	-5.372	-5.327	-5.282	-5.237	-100
-90	-5.237	-5.192	-5.147	-5.101	-5.055	-5.009	-4.963	-4.917	-4.871	-4.824	-4.777	-90
-80	-4.777	-4.731	-4.684	-4.636	-4.589	-4.542	-4.494	-4.446	-4.398	-4.350	-4.302	-80
-70	-4.302	-4.254	-4.205	-4.156	-4.107	-4.058	-4.009	-3.960	-3.911	-3.861	-3.811	-70
-60	-3.811	-3.761	-3.711	-3.661	-3.611	-3.561	-3.510	-3.459	-3.408	-3.357	-3.306	-60
-50	-3.306	-3.255	-3.204	-3.152	-3.100	-3.048	-2.996	-2.944	-2.892	-2.840	-2.787	-50
-40	-2.787	-2.735	-2.682	-2.629	-2.576	-2.523	-2.469	-2.416	-2.362	-2.309	-2.255	-40
-30	-2.255	-2.201	-2.147	-2.093	-2.038	-1.984	-1.929	-1.874	-1.820	-1.765	-1.709	-30
-20	-1.709	-1.654	-1.599	-1.543	-1.488	-1.432	-1.376	-1.320	-1.264	-1.208	-1.152	-20
-10	-1.152	-1.095	-1.039	-0.982	-0.925	-0.868	-0.811	-0.754	-0.697	-0.639	-0.582	-10
0	-0.582	-0.524	-0.466	-0.408	-0.350	-0.292	-0.234	-0.176	-0.117	-0.059	0.000	0

°C	0	1	2	3	4	5	6	7	8	9	10	°C
0	0.000	0.059	0.118	0.176	0.235	0.294	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	1.010	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	1.740	1.801	20
30	1.801	1.862	1.924	1.986	2.047	2.109	2.171	2.233	2.295	2.357	2.420	30
40	2.420	2.482	2.545	2.607	2.670	2.733	2.795	2.858	2.921	2.984	3.048	40
50	3.048	3.111	3.174	3.238	3.301	3.365	3.429	3.492	3.556	3.620	3.685	50
60	3.685	3.749	3.813	3.877	3.942	4.006	4.071	4.136	4.200	4.265	4.330	60
70	4.330	4.395	4.460	4.526	4.591	4.656	4.722	4.788	4.853	4.919	4.985	70
80	4.985	5.051	5.117	5.183	5.249	5.315	5.382	5.448	5.514	5.581	5.648	80
90	5.648	5.714	5.781	5.848	5.915	5.982	6.049	6.117	6.184	6.251	6.319	90
100	6.319	6.386	6.454	6.522	6.590	6.658	6.725	6.794	6.862	6.930	6.998	100
110	6.998	7.066	7.135	7.203	7.272	7.341	7.409	7.478	7.547	7.616	7.685	110
120	7.685	7.754	7.823	7.892	7.962	8.031	8.101	8.170	8.240	8.309	8.379	120
130	8.379	8.449	8.519	8.589	8.659	8.729	8.799	8.869	8.940	9.010	9.081	130
140	9.081	9.151	9.222	9.292	9.363	9.434	9.505	9.576	9.647	9.718	9.789	140
150	9.789	9.860	9.931	10.003	10.074	10.145	10.217	10.288	10.360	10.432	10.503	150
160	10.503	10.575	10.647	10.719	10.791	10.863	10.935	11.007	11.080	11.152	11.224	160
170	11.224	11.297	11.369	11.442	11.514	11.587	11.660	11.733	11.805	11.878	11.951	170
180	11.951	12.024	12.097	12.170	12.243	12.317	12.390	12.463	12.537	12.610	12.684	180
190	12.684	12.757	12.831	12.904	12.978	13.052	13.126	13.199	13.273	13.347	13.421	190
200	13.421	13.495	13.569	13.644	13.718	13.792	13.866	13.941	14.015	14.090	14.164	200
210	14.164	14.239	14.313	14.388	14.463	14.537	14.612	14.687	14.762	14.837	14.912	210
220	14.912	14.987	15.062	15.137	15.212	15.287	15.362	15.438	15.513	15.588	15.664	220
230	15.664	15.739	15.815	15.890	15.966	16.041	16.117	16.193	16.269	16.344	16.420	230
240	16.420	16.496	16.572	16.648	16.724	16.800	16.876	16.952	17.028	17.104	17.181	240
250	17.181	17.257	17.333	17.409	17.486	17.562	17.639	17.715	17.792	17.868	17.945	250
260	17.945	18.021	18.098	18.175	18.252	18.328	18.405	18.482	18.559	18.636	18.713	260
270	18.713	18.790	18.867	18.944	19.021	19.098	19.175	19.252	19.330	19.407	19.484	270
280	19.484	19.561	19.639	19.716	19.794	19.871	19.948	20.026	20.103	20.181	20.259	280
290	20.259	20.336	20.414	20.492	20.569	20.647	20.725	20.803	20.880	20.958	21.036	290
300	21.036	21.114	21.192	21.270	21.348	21.426	21.504	21.582	21.660	21.739	21.817	300
310	21.817	21.895	21.973	22.051	22.130	22.208	22.286	22.365	22.443	22.522	22.600	310
320	22.600	22.678	22.757	22.835	22.914	22.993	23.071	23.150	23.228	23.307	23.386	320
330	23.386	23.464	23.543	23.622	23.701	23.780	23.858	23.937	24.016	24.095	24.174	330
340	24.174	24.253	24.332	24.411	24.490	24.569	24.648	24.727	24.806	24.885	24.964	340

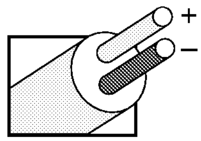
°C	0	1	2	3	4	5	6	7	8	9	10	°C
350	24.964	25.044	25.123	25.202	25.281	25.360	25.440	25.519	25.598	25.678	25.757	350
360	25.757	25.836	25.916	25.995	26.075	26.154	26.233	26.313	26.392	26.472	26.552	360
370	26.552	26.631	26.711	26.790	26.870	26.950	27.029	27.109	27.189	27.268	27.348	370
380	27.348	27.428	27.507	27.587	27.667	27.747	27.827	27.907	27.986	28.066	28.146	380
390	28.146	28.226	28.306	28.386	28.466	28.546	28.626	28.706	28.786	28.866	28.946	390
400	28.946	29.026	29.106	29.186	29.266	29.346	29.427	29.507	29.587	29.667	29.747	400
410	29.747	29.827	29.908	29.988	30.068	30.148	30.229	30.309	30.389	30.470	30.550	410
420	30.550	30.630	30.711	30.791	30.871	30.952	31.032	31.112	31.193	31.273	31.354	420
430	31.354	31.434	31.515	31.595	31.676	31.756	31.837	31.917	31.998	32.078	32.159	430
440	32.159	32.239	32.320	32.400	32.481	32.562	32.642	32.723	32.803	32.884	32.965	440
450	32.965	33.045	33.126	33.207	33.287	33.368	33.449	33.529	33.610	33.691	33.772	450
460	33.772	33.852	33.933	34.014	34.095	34.175	34.256	34.337	34.418	34.498	34.579	460
470	34.579	34.660	34.741	34.822	34.902	34.983	35.064	35.145	35.226	35.307	35.387	470
480	35.387	35.468	35.549	35.630	35.711	35.792	35.873	35.954	36.034	36.115	36.196	480
490	36.196	36.277	36.358	36.439	36.520	36.601	36.682	36.763	36.843	36.924	37.005	490
500	37.005	37.086	37.167	37.248	37.329	37.410	37.491	37.572	37.653	37.734	37.815	500
510	37.815	37.896	37.977	38.058	38.139	38.220	38.300	38.381	38.462	38.543	38.624	510
520	38.624	38.705	38.786	38.867	38.948	39.029	39.110	39.191	39.272	39.353	39.434	520
530	39.434	39.515	39.596	39.677	39.758	39.839	39.920	40.001	40.082	40.163	40.243	530
540	40.243	40.324	40.405	40.486	40.567	40.648	40.729	40.810	40.891	40.972	41.053	540
550	41.053	41.134	41.215	41.296	41.377	41.457	41.538	41.619	41.700	41.781	41.862	550
560	41.862	41.943	42.024	42.105	42.185	42.266	42.347	42.428	42.509	42.590	42.671	560
570	42.671	42.751	42.832	42.913	42.994	43.075	43.156	43.236	43.317	43.398	43.479	570
580	43.479	43.560	43.640	43.721	43.802	43.883	43.963	44.044	44.125	44.206	44.286	580
590	44.286	44.367	44.448	44.529	44.609	44.690	44.771	44.851	44.932	45.013	45.093	590
600	45.093	45.174	45.255	45.335	45.416	45.497	45.577	45.658	45.738	45.819	45.900	600
610	45.900	45.980	46.061	46.141	46.222	46.302	46.383	46.463	46.544	46.624	46.705	610
620	46.705	46.785	46.866	46.946	47.027	47.107	47.188	47.268	47.349	47.429	47.509	620
630	47.509	47.590	47.670	47.751	47.831	47.911	47.992	48.072	48.152	48.233	48.313	630
640	48.313	48.393	48.474	48.554	48.634	48.715	48.795	48.875	48.955	49.035	49.116	640
650	49.116	49.196	49.276	49.356	49.436	49.517	49.597	49.677	49.757	49.837	49.917	650
660	49.917	49.997	50.077	50.157	50.238	50.318	50.398	50.478	50.558	50.638	50.718	660
670	50.718	50.798	50.878	50.958	51.038	51.118	51.197	51.277	51.357	51.437	51.517	670
680	51.517	51.597	51.677	51.757	51.837	51.916	51.996	52.076	52.156	52.236	52.315	680
690	52.315	52.395	52.475	52.555	52.634	52.714	52.794	52.873	52.953	53.033	53.112	690
700	53.112	53.192	53.272	53.351	53.431	53.510	53.590	53.670	53.749	53.829	53.908	700
710	53.908	53.988	54.067	54.147	54.226	54.306	54.385	54.465	54.544	54.624	54.703	710
720	54.703	54.782	54.862	54.941	55.021	55.100	55.179	55.259	55.338	55.417	55.497	720
730	55.497	55.576	55.655	55.734	55.814	55.893	55.972	56.051	56.131	56.210	56.289	730
740	56.289	56.368	56.447	56.526	56.606	56.685	56.764	56.843	56.922	57.001	57.080	740
750	57.080	57.159	57.238	57.317	57.396	57.475	57.554	57.633	57.712	57.791	57.870	750
760	57.870	57.949	58.028	58.107	58.186	58.265	58.343	58.422	58.501	58.580	58.659	760
770	58.659	58.738	58.816	58.895	58.974	59.053	59.131	59.210	59.289	59.367	59.446	770
780	59.446	59.525	59.604	59.682	59.761	59.839	59.918	59.997	60.075	60.154	60.232	780
790	60.232	60.311	60.390	60.468	60.547	60.625	60.704	60.782	60.860	60.939	61.017	790
800	61.017	61.096	61.174	61.253	61.331	61.409	61.488	61.566	61.644	61.723	61.801	800
810	61.801	61.879	61.958	62.036	62.114	62.192	62.271	62.349	62.427	62.505	62.583	810
820	62.583	62.662	62.740	62.818	62.896	62.974	63.052	63.130	63.208	63.286	63.364	820
830	63.364	63.442	63.520	63.598	63.676	63.754	63.832	63.910	63.988	64.066	64.144	830
840	64.144	64.222	64.300	64.377	64.455	64.533	64.611	64.689	64.766	64.844	64.922	840
850	64.922	65.000	65.077	65.155	65.233	65.310	65.388	65.465	65.543	65.621	65.698	850
860	65.698	65.776	65.853	65.931	66.008	66.086	66.163	66.241	66.318	66.396	66.473	860
870	66.473	66.550	66.628	66.705	66.782	66.860	66.937	67.014	67.092	67.169	67.246	870
880	67.246	67.323	67.400	67.478	67.555	67.632	67.709	67.786	67.863	67.940	68.017	880
890	68.017	68.094	68.171	68.248	68.325	68.402	68.479	68.556	68.633	68.710	68.787	890
900	68.787	68.863	68.940	69.017	69.094	69.171	69.247	69.324	69.401	69.477	69.554	900
910	69.554	69.631	69.707	69.784	69.860	69.937	70.013	70.090	70.166	70.243	70.319	910
920	70.319	70.396	70.472	70.548	70.625	70.701	70.777	70.854	70.930	71.006	71.082	920
930	71.082	71.159	71.235	71.311	71.387	71.463	71.539	71.615	71.692	71.768	71.844	930
940	71.844	71.920	71.996	72.072	72.147	72.223	72.299	72.375	72.451	72.527	72.603	940
950	72.603	72.678	72.754	72.830	72.906	72.981	73.057	73.133	73.208	73.284	73.360	950
960	73.360	73.435	73.511	73.586	73.662	73.738	73.813	73.889	73.964	74.040	74.115	960
970	74.115	74.190	74.266	74.341	74.417	74.492	74.567	74.643	74.718	74.793	74.869	970
980	74.869	74.944	75.019	75.095	75.170	75.245	75.320	75.395	75.471	75.546	75.621	980
990	75.621	75.696	75.771	75.847	75.922	75.997	76.072	76.147	76.223	76.298	76.373	990
°C	0	1	2	3	4	5	6	7	8	9	10	°C

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
– 328 to 2282°F
– 200 to 1250°C
Extension Grade
32 to 392°F
0 to 200°C
LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75% Above 0°C
2.2°C or 2.0% Below 0°C
Special: 1.1°C or 0.4%
COMMENTS, BARE WIRE ENVIRONMENT:
Clean Oxidizing and Inert; Limited Use in Vacuum or Reducing; Wide Temperature Range; Most Popular Calibration
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C



Thermocouple Grade

Nickel-Chromium vs. Nickel-Aluminum



Extension Grade

Revised Thermocouple Reference Tables

TYPE K

Reference Tables N.I.S.T. Monograph 175 Revised to ITS-90

Z

Thermoelectric Voltage in Millivolts

°C	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	°C
-260	-6.458	-6.457	-6.456	-6.455	-6.453	-6.452	-6.450	-6.448	-6.446	-6.444	-6.441	-260
-250	-6.441	-6.438	-6.435	-6.432	-6.429	-6.425	-6.421	-6.417	-6.413	-6.408	-6.404	-250
-240	-6.404	-6.399	-6.393	-6.388	-6.382	-6.377	-6.370	-6.364	-6.358	-6.351	-6.344	-240
-230	-6.344	-6.337	-6.329	-6.322	-6.314	-6.306	-6.297	-6.289	-6.280	-6.271	-6.262	-230
-220	-6.262	-6.252	-6.243	-6.233	-6.223	-6.213	-6.202	-6.192	-6.181	-6.170	-6.158	-220
-210	-6.158	-6.147	-6.135	-6.123	-6.111	-6.099	-6.087	-6.074	-6.061	-6.048	-6.035	-210
-200	-6.035	-6.021	-6.007	-5.994	-5.980	-5.965	-5.951	-5.936	-5.922	-5.907	-5.891	-200
-190	-5.891	-5.876	-5.861	-5.845	-5.829	-5.813	-5.797	-5.780	-5.763	-5.747	-5.730	-190
-180	-5.730	-5.713	-5.695	-5.678	-5.660	-5.642	-5.624	-5.606	-5.588	-5.569	-5.550	-180
-170	-5.550	-5.531	-5.512	-5.493	-5.474	-5.454	-5.435	-5.415	-5.395	-5.374	-5.354	-170
-160	-5.354	-5.333	-5.313	-5.292	-5.271	-5.250	-5.228	-5.207	-5.185	-5.163	-5.141	-160
-150	-5.141	-5.119	-5.097	-5.074	-5.052	-5.029	-5.006	-4.983	-4.960	-4.936	-4.913	-150
-140	-4.913	-4.889	-4.865	-4.841	-4.817	-4.793	-4.768	-4.744	-4.719	-4.694	-4.669	-140
-130	-4.669	-4.644	-4.618	-4.593	-4.567	-4.542	-4.516	-4.490	-4.463	-4.437	-4.411	-130
-120	-4.411	-4.384	-4.357	-4.330	-4.303	-4.276	-4.249	-4.221	-4.194	-4.166	-4.138	-120
-110	-4.138	-4.110	-4.082	-4.054	-4.025	-3.997	-3.968	-3.939	-3.911	-3.882	-3.852	-110
-100	-3.852	-3.823	-3.794	-3.764	-3.734	-3.705	-3.675	-3.645	-3.614	-3.584	-3.554	-100
-90	-3.554	-3.523	-3.492	-3.462	-3.431	-3.400	-3.368	-3.337	-3.306	-3.274	-3.243	-90
-80	-3.243	-3.211	-3.179	-3.147	-3.115	-3.083	-3.050	-3.018	-2.986	-2.953	-2.920	-80
-70	-2.920	-2.887	-2.854	-2.821	-2.788	-2.755	-2.721	-2.688	-2.654	-2.620	-2.587	-70
-60	-2.587	-2.553	-2.519	-2.485	-2.450	-2.416	-2.382	-2.347	-2.312	-2.278	-2.243	-60
-50	-2.243	-2.208	-2.173	-2.138	-2.103	-2.067	-2.032	-1.996	-1.961	-1.925	-1.889	-50
-40	-1.889	-1.854	-1.818	-1.782	-1.745	-1.709	-1.673	-1.637	-1.600	-1.564	-1.527	-40
-30	-1.527	-1.490	-1.453	-1.417	-1.380	-1.343	-1.305	-1.268	-1.231	-1.194	-1.156	-30
-20	-1.156	-1.119	-1.081	-1.043	-1.006	-0.968	-0.930	-0.892	-0.854	-0.816	-0.778	-20
-10	-0.778	-0.739	-0.701	-0.663	-0.624	-0.586	-0.547	-0.508	-0.470	-0.431	-0.392	-10
0	-0.392	-0.353	-0.314	-0.275	-0.236	-0.197	-0.157	-0.118	-0.079	-0.039	0.000	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	1.163	1.203	20
30	1.203	1.244	1.285	1.326	1.366	1.407	1.448	1.489	1.530	1.571	1.612	30
40	1.612	1.653	1.694	1.735	1.776	1.817	1.858	1.899	1.941	1.982	2.023	40
50	2.023	2.064	2.106	2.147	2.188	2.230	2.271	2.312	2.354	2.395	2.436	50
60	2.436	2.478	2.519	2.561	2.602	2.644	2.685	2.727	2.768	2.810	2.851	60
70	2.851	2.893	2.934	2.976	3.017	3.059	3.100	3.142	3.184	3.225	3.267	70
80	3.267	3.308	3.350	3.391	3.433	3.474	3.516	3.557	3.599	3.640	3.682	80
90	3.682	3.723	3.765	3.806	3.848	3.889	3.931	3.972	4.013	4.055	4.096	90
100	4.096	4.138	4.179	4.220	4.262	4.303	4.344	4.385	4.427	4.468	4.509	100
110	4.509	4.550	4.591	4.633	4.674	4.715	4.756	4.797	4.838	4.879	4.920	110
120	4.920	4.961	5.002	5.043	5.084	5.124	5.165	5.206	5.247	5.288	5.328	120
130	5.328	5.369	5.410	5.450	5.491	5.532	5.572	5.613	5.653	5.694	5.735	130
140	5.735	5.775	5.815	5.856	5.896	5.937	5.977	6.017	6.058	6.098	6.138	140
150	6.138	6.179	6.219	6.259	6.299	6.339	6.380	6.420	6.460	6.500	6.540	150
160	6.540	6.580	6.620	6.660	6.701	6.741	6.781	6.821	6.861	6.901	6.941	160
170	6.941	6.981	7.021	7.060	7.100	7.140	7.180	7.220	7.260	7.300	7.340	170
180	7.340	7.380	7.420	7.460	7.500	7.540	7.579	7.619	7.659	7.699	7.739	180
190	7.739	7.779	7.819	7.859	7.899	7.939	7.979	8.019	8.059	8.099	8.138	190
200	8.138	8.178	8.218	8.258	8.298	8.338	8.378	8.418	8.458	8.499	8.539	200
210	8.539	8.579	8.619	8.659	8.699	8.739	8.779	8.819	8.860	8.900	8.940	210
220	8.940	8.980	9.020	9.061	9.101	9.141	9.181	9.222	9.262	9.302	9.343	220
230	9.343	9.383	9.423	9.464	9.504	9.545	9.585	9.626	9.666	9.707	9.747	230
240	9.747	9.788	9.828	9.869	9.909	9.950	9.991	10.031	10.072	10.113	10.153	240
°C	0	1	2	3	4	5	6	7	8	9	10	°C

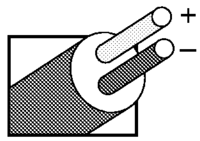
°C	0	1	2	3	4	5	6	7	8	9	10	°C
250	10.153	10.194	10.235	10.276	10.316	10.357	10.398	10.439	10.480	10.520	10.561	250
260	10.561	10.602	10.643	10.684	10.725	10.766	10.807	10.848	10.889	10.930	10.971	260
270	10.971	11.012	11.053	11.094	11.135	11.176	11.217	11.259	11.300	11.341	11.382	270
280	11.382	11.423	11.465	11.506	11.547	11.588	11.630	11.671	11.712	11.753	11.795	280
290	11.795	11.836	11.877	11.919	11.960	12.001	12.043	12.084	12.126	12.167	12.209	290
300	12.209	12.250	12.291	12.333	12.374	12.416	12.457	12.499	12.540	12.582	12.624	300
310	12.624	12.665	12.707	12.748	12.790	12.831	12.873	12.915	12.956	12.998	13.040	310
320	13.040	13.081	13.123	13.165	13.206	13.248	13.290	13.331	13.373	13.415	13.457	320
330	13.457	13.498	13.540	13.582	13.624	13.665	13.707	13.749	13.791	13.833	13.874	330
340	13.874	13.916	13.958	14.000	14.042	14.084	14.126	14.167	14.209	14.251	14.293	340
350	14.293	14.335	14.377	14.419	14.461	14.503	14.545	14.587	14.629	14.671	14.713	350
360	14.713	14.755	14.797	14.839	14.881	14.923	14.965	15.007	15.049	15.091	15.133	360
370	15.133	15.175	15.217	15.259	15.301	15.343	15.385	15.427	15.469	15.511	15.554	370
380	15.554	15.596	15.638	15.680	15.722	15.764	15.806	15.849	15.891	15.933	15.975	380
390	15.975	16.017	16.059	16.102	16.144	16.186	16.228	16.270	16.313	16.355	16.397	390
400	16.397	16.439	16.482	16.524	16.566	16.608	16.651	16.693	16.735	16.778	16.820	400
410	16.820	16.862	16.904	16.947	16.989	17.031	17.074	17.116	17.158	17.201	17.243	410
420	17.243	17.285	17.328	17.370	17.413	17.455	17.497	17.540	17.582	17.624	17.667	420
430	17.667	17.709	17.752	17.794	17.837	17.879	17.921	17.964	18.006	18.049	18.091	430
440	18.091	18.134	18.176	18.218	18.261	18.303	18.346	18.388	18.431	18.473	18.516	440
450	18.516	18.558	18.601	18.643	18.686	18.728	18.771	18.813	18.856	18.898	18.941	450
460	18.941	18.983	19.026	19.068	19.111	19.154	19.196	19.239	19.281	19.324	19.366	460
470	19.366	19.409	19.451	19.494	19.537	19.579	19.622	19.664	19.707	19.750	19.792	470
480	19.792	19.835	19.877	19.920	19.962	20.005	20.048	20.090	20.133	20.175	20.218	480
490	20.218	20.261	20.303	20.346	20.389	20.431	20.474	20.516	20.559	20.602	20.644	490
500	20.644	20.687	20.730	20.772	20.815	20.857	20.900	20.943	20.985	21.028	21.071	500
510	21.071	21.113	21.156	21.199	21.241	21.284	21.326	21.369	21.412	21.454	21.497	510
520	21.497	21.540	21.582	21.625	21.668	21.710	21.753	21.796	21.838	21.881	21.924	520
530	21.924	21.966	22.009	22.052	22.094	22.137	22.179	22.222	22.265	22.307	22.350	530
540	22.350	22.393	22.435	22.478	22.521	22.563	22.606	22.649	22.691	22.734	22.776	540
550	22.776	22.819	22.862	22.904	22.947	22.990	23.032	23.075	23.117	23.160	23.203	550
560	23.203	23.245	23.288	23.331	23.373	23.416	23.458	23.501	23.544	23.586	23.629	560
570	23.629	23.671	23.714	23.757	23.799	23.842	23.884	23.927	23.970	24.012	24.055	570
580	24.055	24.097	24.140	24.182	24.225	24.267	24.310	24.353	24.395	24.438	24.480	580
590	24.480	24.523	24.565	24.608	24.650	24.693	24.735	24.778	24.820	24.863	24.905	590
600	24.905	24.948	24.990	25.033	25.075	25.118	25.160	25.203	25.245	25.288	25.330	600
610	25.330	25.373	25.415	25.458	25.500	25.543	25.585	25.627	25.670	25.712	25.755	610
620	25.755	25.797	25.840	25.882	25.924	25.967	26.009	26.052	26.094	26.136	26.179	620
630	26.179	26.221	26.263	26.306	26.348	26.390	26.433	26.475	26.517	26.560	26.602	630
640	26.602	26.644	26.687	26.729	26.771	26.814	26.856	26.898	26.940	26.983	27.025	640
650	27.025	27.067	27.109	27.152	27.194	27.236	27.278	27.320	27.363	27.405	27.447	650
660	27.447	27.489	27.531	27.574	27.616	27.658	27.700	27.742	27.784	27.826	27.869	660
670	27.869	27.911	27.953	27.995	28.037	28.079	28.121	28.163	28.205	28.247	28.289	670
680	28.289	28.332	28.374	28.416	28.458	28.500	28.542	28.584	28.626	28.668	28.710	680
690	28.710	28.752	28.794	28.835	28.877	28.919	28.961	29.003	29.045	29.087	29.129	690
700	29.129	29.171	29.213	29.255	29.297	29.338	29.380	29.422	29.464	29.506	29.548	700
710	29.548	29.589	29.631	29.673	29.715	29.757	29.798	29.840	29.882	29.924	29.965	710
720	29.965	30.007	30.049	30.090	30.132	30.174	30.216	30.257	30.299	30.341	30.382	720
730	30.382	30.424	30.466	30.507	30.549	30.590	30.632	30.674	30.715	30.757	30.798	730
740	30.798	30.840	30.881	30.923	30.964	31.006	31.047	31.089	31.130	31.172	31.213	740
750	31.213	31.255	31.296	31.338	31.379	31.421	31.462	31.504	31.545	31.586	31.628	750
760	31.628	31.669	31.710	31.752	31.793	31.834	31.876	31.917	31.958	32.000	32.041	760
770	32.041	32.082	32.124	32.165	32.206	32.247	32.289	32.330	32.371	32.412	32.453	770
780	32.453	32.495	32.536	32.577	32.618	32.659	32.700	32.742	32.783	32.824	32.865	780
790	32.865	32.906	32.947	32.988	33.029	33.070	33.111	33.152	33.193	33.234	33.275	790
°C	0	1	2	3	4	5	6	7	8	9	10	°C

Revised Thermocouple Reference Tables

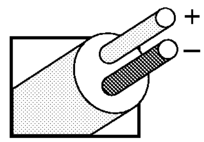
TYPE K

Reference Tables
N.I.S.T. Monograph 175
Revised to ITS-90

Thermocouple Grade



Nickel-Chromium vs. Nickel-Aluminum



Extension Grade

MAXIMUM TEMPERATURE RANGE
Thermocouple Grade
– 328 to 2282°F
– 200 to 1250°C
Extension Grade
32 to 392°F
0 to 200°C
LIMITS OF ERROR
(whichever is greater)
Standard: 2.2°C or 0.75% Above 0°C
2.2°C or 2.0% Below 0°C
Special: 1.1°C or 0.4%
COMMENTS, BARE WIRE ENVIRONMENT:
Clean Oxidizing and Inert; Limited Use in Vacuum or Reducing; Wide Temperature Range; Most Popular Calibration
TEMPERATURE IN DEGREES °C
REFERENCE JUNCTION AT 0°C

Thermoelectric Voltage in Millivolts

°C	0	1	2	3	4	5	6	7	8	9	10	°C
800	33.275	33.316	33.357	33.398	33.439	33.480	33.521	33.562	33.603	33.644	33.685	800
810	33.685	33.726	33.767	33.808	33.848	33.889	33.930	33.971	34.012	34.053	34.093	810
820	34.093	34.134	34.175	34.216	34.257	34.297	34.338	34.379	34.420	34.460	34.501	820
830	34.501	34.542	34.582	34.623	34.664	34.704	34.745	34.786	34.826	34.867	34.908	830
840	34.908	34.948	34.989	35.029	35.070	35.110	35.151	35.192	35.232	35.273	35.313	840
850	35.313	35.354	35.394	35.435	35.475	35.516	35.556	35.596	35.637	35.677	35.718	850
860	35.718	35.758	35.798	35.839	35.879	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	36.484	36.524	870
880	36.524	36.564	36.604	36.644	36.685	36.725	36.765	36.805	36.845	36.885	36.925	880
890	36.925	36.965	37.006	37.046	37.086	37.126	37.166	37.206	37.246	37.286	37.326	890
900	37.326	37.366	37.406	37.446	37.486	37.526	37.566	37.606	37.646	37.686	37.725	900
910	37.725	37.765	37.805	37.845	37.885	37.925	37.965	38.005	38.044	38.084	38.124	910
920	38.124	38.164	38.204	38.243	38.283	38.323	38.363	38.402	38.442	38.482	38.522	920
930	38.522	38.561	38.601	38.641	38.680	38.720	38.760	38.799	38.839	38.878	38.918	930
940	38.918	38.958	38.997	39.037	39.076	39.116	39.155	39.195	39.235	39.274	39.314	940
950	39.314	39.353	39.393	39.432	39.471	39.511	39.550	39.590	39.629	39.669	39.708	950
960	39.708	39.747	39.787	39.826	39.866	39.905	39.944	39.984	40.023	40.062	40.101	960
970	40.101	40.141	40.180	40.219	40.259	40.298	40.337	40.376	40.415	40.455	40.494	970
980	40.494	40.533	40.572	40.611	40.651	40.690	40.729	40.768	40.807	40.846	40.885	980
990	40.885	40.924	40.963	41.002	41.042	41.081	41.120	41.159	41.198	41.237	41.276	990
1000	41.276	41.315	41.354	41.393	41.431	41.470	41.509	41.548	41.587	41.626	41.665	1000
1010	41.665	41.704	41.743	41.781	41.820	41.859	41.898	41.937	41.976	42.014	42.053	1010
1020	42.053	42.092	42.131	42.169	42.208	42.247	42.286	42.324	42.363	42.402	42.440	1020
1030	42.440	42.479	42.518	42.556	42.595	42.633	42.672	42.711	42.749	42.788	42.826	1030
1040	42.826	42.865	42.903	42.942	42.980	43.019	43.057	43.096	43.134	43.173	43.211	1040
1050	43.211	43.250	43.288	43.327	43.365	43.403	43.442	43.480	43.518	43.557	43.595	1050
1060	43.595	43.633	43.672	43.710	43.748	43.787	43.825	43.863	43.901	43.940	43.978	1060
1070	43.978	44.016	44.054	44.092	44.130	44.169	44.207	44.245	44.283	44.321	44.359	1070
1080	44.359	44.397	44.435	44.473	44.512	44.550	44.588	44.626	44.664	44.702	44.740	1080
1090	44.740	44.778	44.816	44.853	44.891	44.929	44.967	45.005	45.043	45.081	45.119	1090
°C	0	1	2	3	4	5	6	7	8	9	10	°C

°C	0	1	2	3	4	5	6	7	8	9	10	°C
1100	45.119	45.157	45.194	45.232	45.270	45.308	45.346	45.383	45.421	45.459	45.497	1100
1110	45.497	45.534	45.572	45.610	45.647	45.685	45.723	45.760	45.798	45.836	45.873	1110
1120	45.873	45.911	45.948	45.986	46.024	46.061	46.099	46.136	46.174	46.211	46.249	1120
1130	46.249	46.286	46.324	46.361	46.398	46.436	46.473	46.511	46.548	46.585	46.623	1130
1140	46.623	46.660	46.697	46.735	46.772	46.809	46.847	46.884	46.921	46.958	46.995	1140
1150	46.995	47.033	47.070	47.107	47.144	47.181	47.218	47.256	47.293	47.330	47.367	1150
1160	47.367	47.404	47.441	47.478	47.515	47.552	47.589	47.626	47.663	47.700	47.737	1160
1170	47.737	47.774	47.811	47.848	47.884	47.921	47.958	47.995	48.032	48.069	48.105	1170
1180	48.105	48.142	48.179	48.216	48.252	48.289	48.326	48.363	48.399	48.436	48.473	1180
1190	48.473	48.509	48.546	48.582	48.619	48.656	48.692	48.729	48.765	48.802	48.838	1190
1200	48.838	48.875	48.911	48.948	48.984	49.021	49.057	49.093	49.130	49.166	49.202	1200
1210	49.202	49.239	49.275	49.311	49.348	49.384	49.420	49.456	49.493	49.529	49.565	1210
1220	49.565	49.601	49.637	49.674	49.710	49.746	49.782	49.818	49.854	49.890	49.926	1220
1230	49.926	49.962	49.998	50.034	50.070	50.106	50.142	50.178	50.214	50.250	50.286	1230
1240	50.286	50.322	50.358	50.393	50.429	50.465	50.501	50.537	50.572	50.608	50.644	1240
1250	50.644	50.680	50.715	50.751	50.787	50.822	50.858	50.894	50.929	50.965	51.000	1250
1260	51.000	51.036	51.071	51.107	51.142	51.178	51.213	51.249	51.284	51.320	51.355	1260
1270	51.355	51.391	51.426	51.461	51.497	51.532	51.567	51.603	51.638	51.673	51.708	1270
1280	51.708	51.744	51.779	51.814	51.849	51.885	51.920	51.955	51.990	52.025	52.060	1280
1290	52.060	52.095	52.130	52.165	52.200	52.235	52.270	52.305	52.340	52.375	52.410	1290
1300	52.410	52.445	52.480	52.515	52.550	52.585	52.620	52.654	52.689	52.724	52.759	1300
1310	52.759	52.794	52.828	52.863	52.898	52.932	52.967	53.002	53.037	53.071	53.106	1310
1320	53.106	53.140	53.175	53.210	53.244	53.279	53.313	53.348	53.382	53.417	53.451	1320
1330	53.451	53.486	53.520	53.555	53.589	53.623	53.658	53.692	53.727	53.761	53.795	1330
1340	53.795	53.830	53.864	53.898	53.932	53.967	54.001	54.035	54.069	54.104	54.138	1340
1350	54.138	54.172	54.206	54.240	54.274	54.308	54.343	54.377	54.411	54.445	54.479	1350
1360	54.479	54.513	54.547	54.581	54.615	54.649	54.683	54.717	54.751	54.785	54.819	1360
1370	54.819	54.852	54.886									1370
°C	0	1	2	3	4	5	6	7	8	9	10	°C