LAKEWOOD SYSTEMS LTD.
Remote Data Recording Products

IPT
Rain-tight Input Plug
&
TP-X
Temperature Probes

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1 Introduction

The IPT is a unique input plug with screw terminals, at one end, to allow easy hookup of thermistor temperature sensors. The other end has a connector that will connect to an RXP External Plug Assembly. This allows easy connection to many Lakewood Systems products such as the RX Data Storage Unit and the Chart Pac The screw terminals are also protected from the environment by use of a Rubber Boot Cover. With the use of advanced electronics, the IPT converts a thermistor's resistance into a 0 to 2.5 Volt output. The IPT features a quick response time (35 milliseconds), low power consumption, wide operating temperature range and sensor excitation. This makes the IPT perfect for interfacing to TPX temperature probes.

1.1 Terminal Assignments

The four screw terminals are used to connect the sensor. If the sensor does not need excitation power, only two of these terminals are used. The first screw terminal (1) is common ground. The second screw terminal (2) is an analog input that has a useful input range of 0 to 2.5 Volts. It has a 9990W input impedance to terminate the Thermistor. The next two screw terminals (3 and 4) offer excitation for the sensor. The third screw terminal (3) is a precision 2.500 Volt excitation output. This output has minimal drive capability (5 milliamperes maximum). The power is pulsed on for a short duration then turned off. The length of the on-time power pulse can be set when programming the datalogger's header. The fourth screw terminal (4) is a B+ switched output. The voltage level of the B+ terminal depends on the battery system being used with the datalogger. The on-time is the same as that for the 2.500V precision excitation output. Fig. 1 shows the position of the screw terminals.

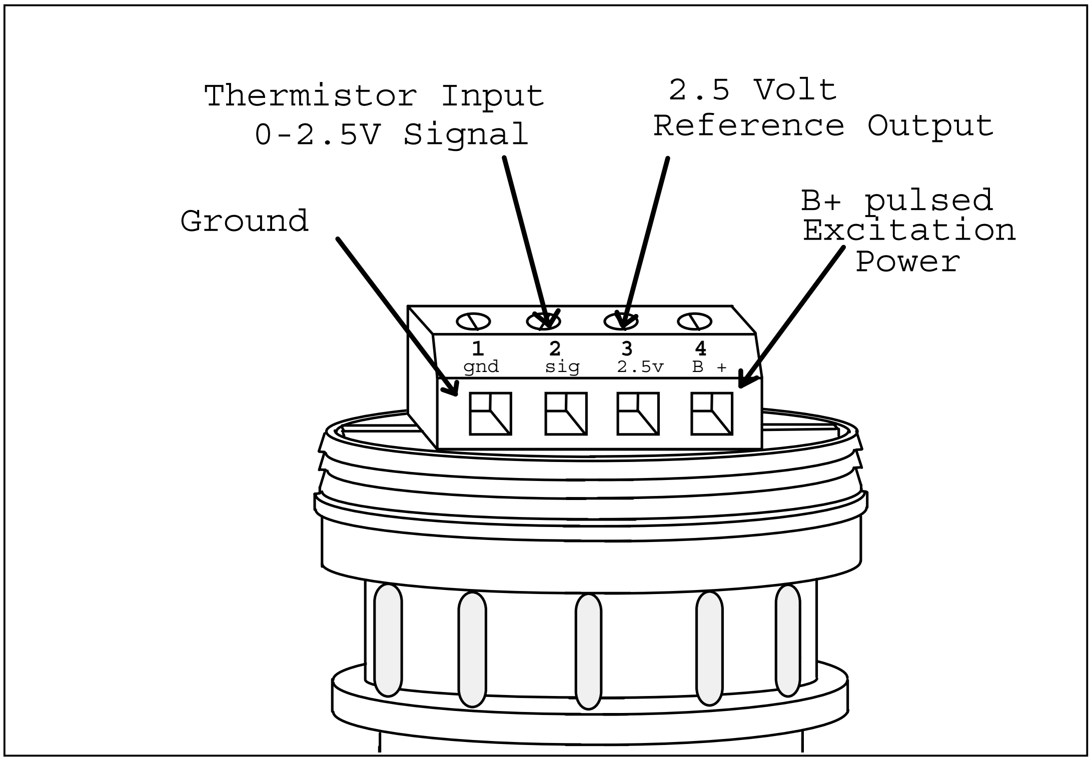

Fig. 1 IPT Terminal assignment.

Make sure the screw terminal is fully open before inserting the wire. A small tug on the wire after tightening can assure the wire is secure.

1.2 Using The Rubber Boot Cover

The rubber boot cover can be used to keep the screw terminals protected from the environment. To use the cover, turn it inside out as shown in Fig. 2 and make a small hole to let the wire through. By using a tywrap, you can then clamp the wire at the position you desire.

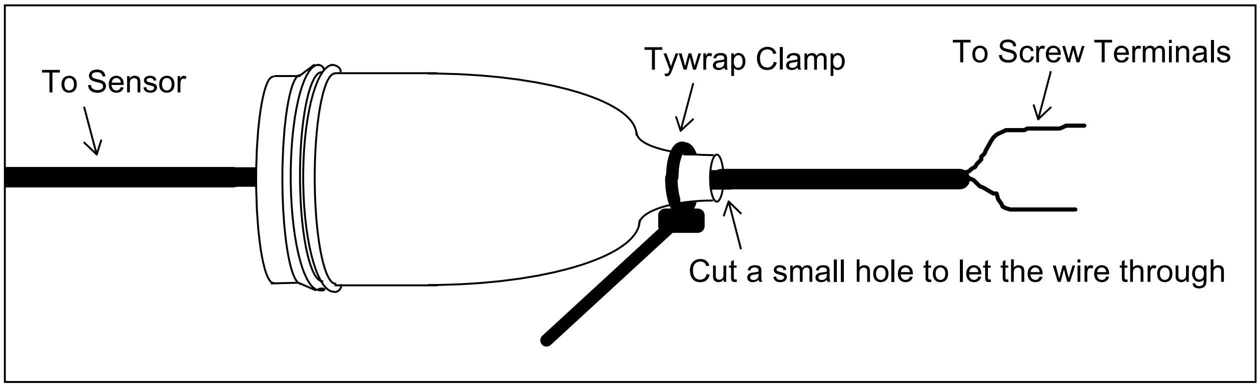

Fig. 2 Preparing the Rubber Boot Cover.

Once you have screwed the wires down and returned the rubber boot cover from the inside out position you can slip it over the screw terminals as shown in Fig. 3 below.

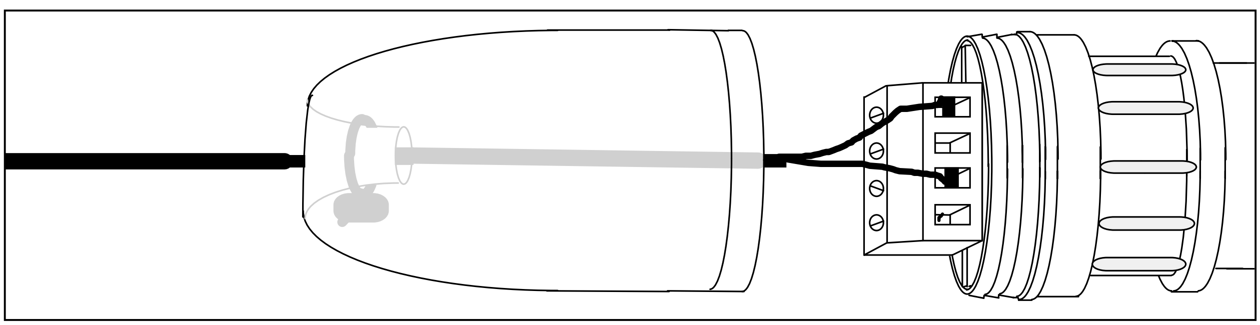

Fig. 3 Final Mounting of the Rubber Boot Cover.

1.3 Software Requirements

The IPT has two settings in the datalogger's programming header that must be correct. The first setting is the warm-up time and the second is a 0 to 2.5 Volt range setting. The example in Fig. 4 below would be used if the IPT was connected to analog channel one and if the probe connected to the IPT did not require a longer excitation warm-up time than 35 milliseconds (60 milliseconds is recommended for lead lengths > 10 meters on the temperature probes). If the excitation warm-up time is too short, the probe's output will differ between AUX PULSED readings and AUX CONTINUOUS readings. AUX PULSED readings are monitor screen values taken when AUX power is being pulsed. AUX CONTINUOUS readings are monitor screen values taken when AUX power is turned on continuously. Keep increasing the warm-up time until the AUX PULSED readings and the AUX CONTINUOUS readings match.

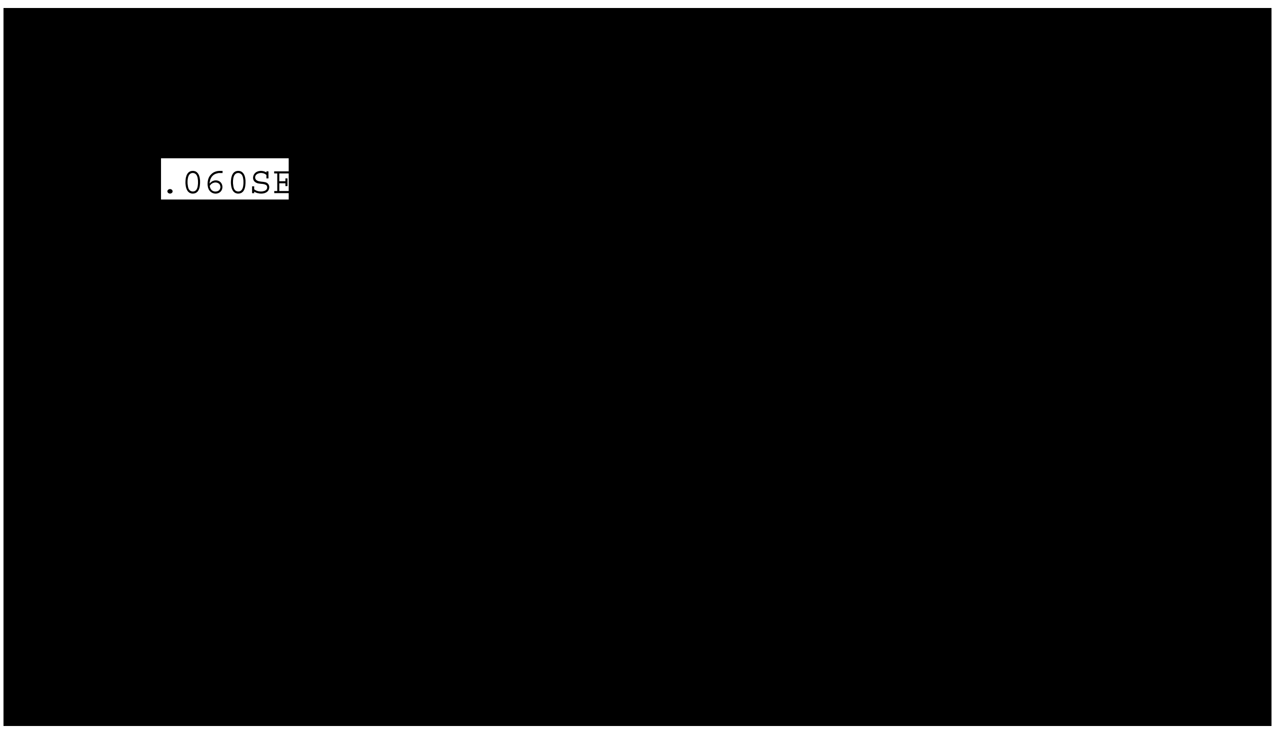

Fig. 4 Example Header Settings

1.4 Entering the IPT into the Library

The IPT converts the resistance of the sensor into 0 to 2.5 Volts. A table of temperature versus voltage appears in Section 3.3 ‘Temperature versus Resistance Table'.

1.5 Creating the Coefficients in the Library

The IPT can be simply entered in the library as a temperature device whose engineering units are displayed in degrees. The coefficients can then be created from resistance tables. Arrows in the screen shown in Fig. 5 point to the seven sections that have to be entered before the coefficients can be calculated. To change TURNED ON (Yes/No) press the BACKSPACE key or the DELETE key until there are no characters in the field. Then type 'Y' for yes then ENTER. The name can be changed to 'IPT' and the description changed to 'IPT Temperature Probe'. You may use the INSERT key to turn overtype on and off. To make room for the characters press the BACKSPACE key or the DELETE key. Just press enter to get to the next line. To edit a line above your current position press enter many times till the menu screen appears. Then choose the current entry. Press enter until you are on the line to be edited. The screen should be exited after making the changes shown in Fig. 5 .

Fig. 5 Library Parameters for an IPT.

The new library entry will be displayed as one of the items in the list as shown in Fig. 6 . Choose the new library entry as the item to edit again. This time when editing the coefficients, the LE8200 software will know that the sensor is of a resistance type.

Fig. 6 Library Menu after adding an IPT.

Move the cursor to the line of COEFF. 0 or any other COEFF. line, as shown in Fig. 7, then press F1 to start the LEAST SQUARES CURVE FITTING.

Fig. 7 Starting the LEAST SQUARES CURVE FITTING.

Select "To Enter New Data Points" by pressing 1 as shown in Fig. 8 then press Enter.

Fig. 8 Selecting the NEW DATA POINTS selection.

From the table of resistance for the TPX temperature probe, we can get the natural log of resistance versus temperature in degrees. This table can be found in the back of this manual. When an IPT is connected to a TPX (5KΩ @25°C thermistor) temperature probe, and we want the engineering units to be outputted in degrees Celsius, our library entries would be as shown in Fig. 9. After entering some values of LN (Resistance) and temperature, enter '999,999' to quit. Next, enter 5 for the degree of polynomial and press ENTER. You can further test and save the curve fit data with different choices on the menu. Press 6 and then ENTER to exit and use the coefficients. The library entry should look like Fig. 10 after you have pressed enter. Press ENTER multiple times until you get back to the menu. Press 'K' to keep the editing that has been done for the IPT entry.

```
-LEAST SQUARES CURVE FITTING -

ENTER A DATA PAIR IN RESPONSE TO EACH QUESTION MARK.
EACH PAIR IS A DATALOGGER VALUE AND AN ENGINEERING UNIT
VALUE SEPARATED BY A COMMA. THIS WILL ALLOW YOU TO
ENTER THE EXPECTED OUTPUTS AT DIFFERENT VOLTAGES.

WHEN YOU HAVE ENTERED ENOUGH POINTS TYPE  999 , 999 TO END.
MAXIMUM OF 60 DATA PAIRS WILL BE ACCEPTED.

Ln(Resistance),Units? 15.119537,-80
Ln(Resistance),Units? 14.259427,-70
Ln(Resistance),Units? 13.462330,-60
Ln(Resistance),Units? 12.722035,-50
Ln(Resistance),Units? 12.033087,-40
Ln(Resistance),Units? 11.390532,-30
Ln(Resistance),Units? 10.790061,-20
Ln(Resistance),Units? 10.227851,-10
Ln(Resistance),Units? 9.700453,0
Ln(Resistance),Units? 9.205278,10
Ln(Resistance),Units? 8.739697,20
Ln(Resistance),Units? 8.301125,30
Ln(Resistance),Units? 7.887284,40
Ln(Resistance),Units? 7.496208,50
Ln(Resistance),Units? 7.126007,60
Ln(Resistance),Units? 6.775138,70
Ln(Resistance),Units? 6.441903,80
Ln(Resistance),Units? 6.126258,90
Ln(Resistance),Units? 5.826885,100
Ln(Resistance),Units? 999,999

 19 DATA PAIRS ENTERED

DEGREE OF POLYNOMIAL TO BE FITTED ? 5

X POWER         COEFFICIENT
   0           451.715984970723
   1          -99.5352056049904
   2           9.51106230415545
   3          -.587570466236592
   4           2.04739909043747D-02
   5          -3.03904029819977D-04

Accuracy of Curve Fit = 99.9999981175215

CONTINUATION OPTIONS
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```
 1 - DETERMINE SPECIFIC POINTS
 2 - FIT ANOTHER DEGREE TO THE SAME DATA
 3 - SAVE COEFFICIENTS TO DISK FOR LOTUS
 4 - SAVE DATA PAIRS TO DISK FOR LOTUS
 5 - LIST TABLE OF CALC. Y POINTS
 6 - EXIT AND USE THE COEFFICIENTS FOR THE PROBE BEING
EDITED
 7 - EXIT AND DISCARD THE FITTED COEFFICIENTS

WHAT NEXT?6
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Fig. 9 Example Library Curve Fitting for an IPT.

Fig. 10 Final Results of IPT Entry

Since we have entered only every tenth degree point of temperature, the coefficients from the example are slightly different than the standard coefficients used for the IPT, TPX and TP10K. The standard coefficients given elsewhere in this manual were calculated with a data point for every degree from -80 to + 100.

2.0 Wiring an IPT to a Temperature Probe.

The IPT can be wired to a temperature sensor. The wiring to a typical temperature sensor is shown in Fig. 11.

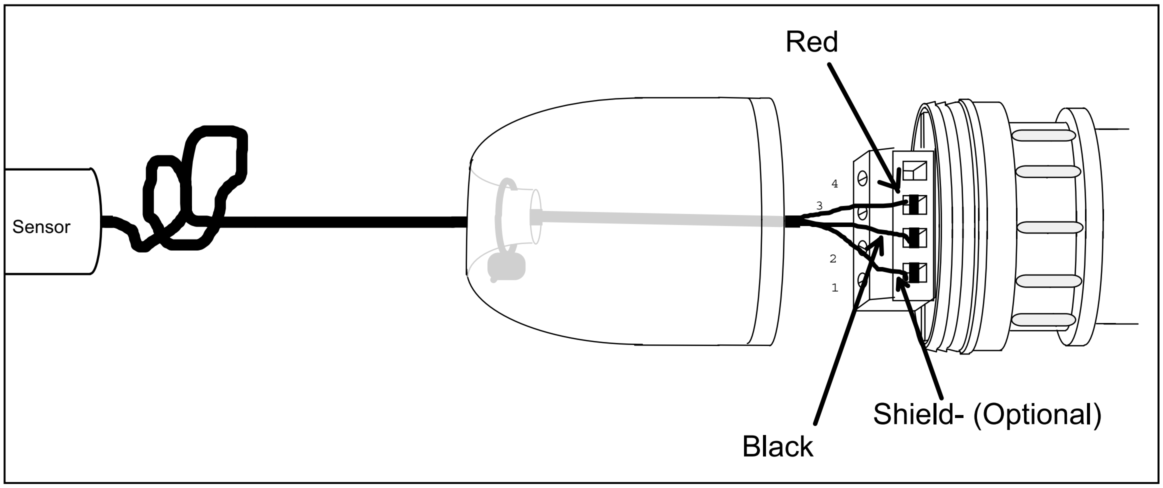

Fig. 11 Temperature Probe Connections.

2.1 RXP External Plug Assembly and IPT

The IPT can be wired to a *UL16 Ultra-Logger* directly through the UL16TBE Terminal Board by using an RXP External Plug Assembly. The wiring and mounting information is shown in the Figure below.

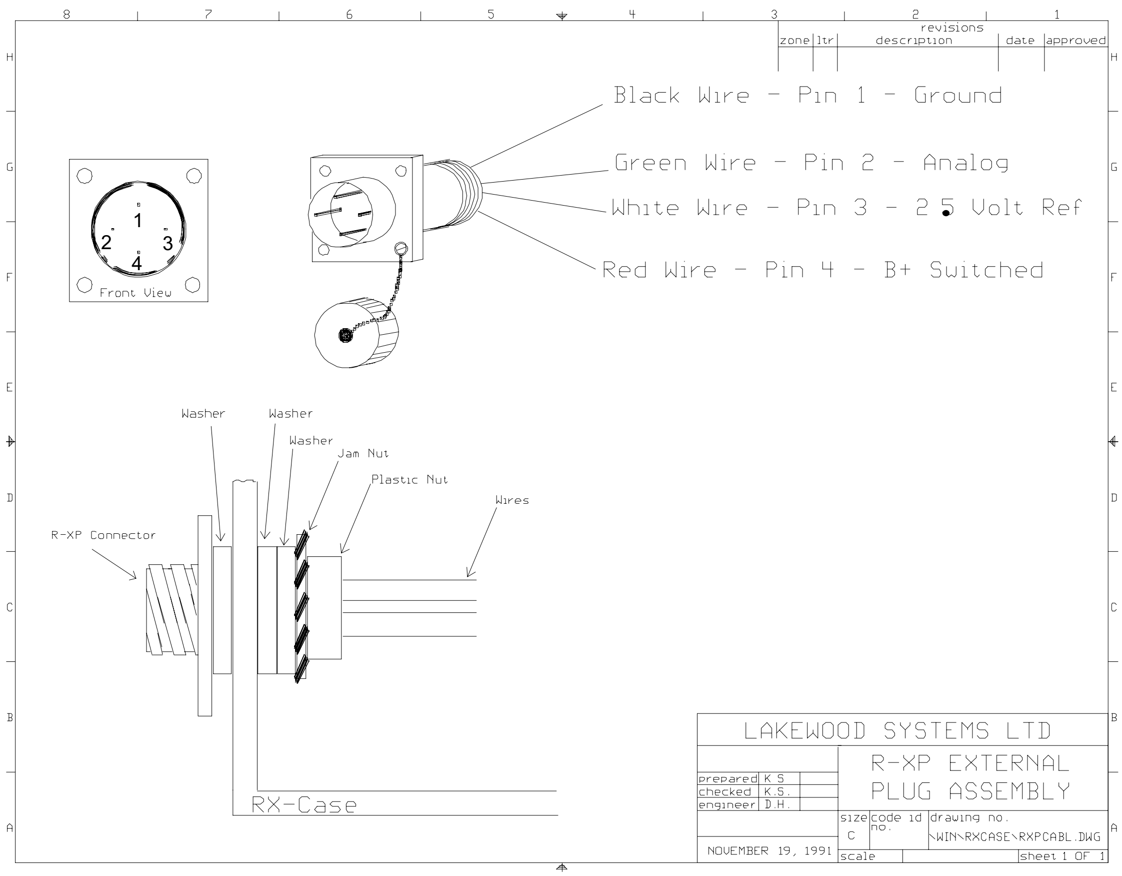

Fig. 12 RXP Wiring and Mounting Information

2.2 Wiring of an TP10K

The wiring connections for a TP10K-X being connected to a UL16TBE terminal board is shown in Fig. 13.

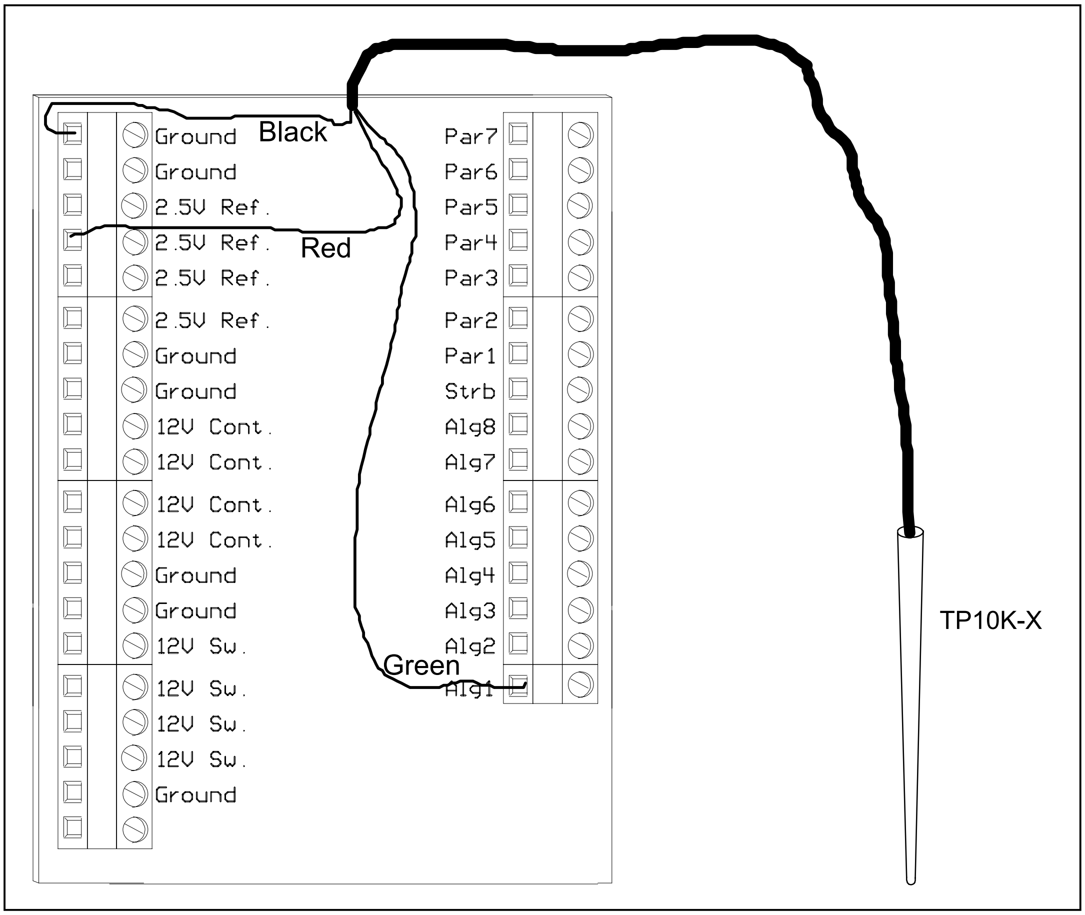

Fig. 13 TP10K to UL16 Terminal Board Connections
(connect TP shield to GND)

3.0 Converting Voltage to Temperature

The following formulas show how to convert the voltage from the half bridge of a thermistor and IPT into temperature. This is done for you in the LE8200/LS4 software and is included here for information purposes only. The TP10K-X (example TP10K20) uses the same formula.

V = Voltage from datalogger (output of IPT or TP10K-X)

X = @LN(((2.5*9901) / V) - 9901)

Temperature = C_0+X*(C_1+X*(C_2+X*(C_3+X*(C_4+(X*C_5)))))

Where the coefficients for **Celsius** are:

C_0 = 448.378448925865115
C_1 = -95.859120175003461
C_2 = 8.361953542603310
C_3 = -0.434098177910065
C_4 = 0.011182629079790
C_5 = -0.000094138790516

Where the coefficients for **Fahrenheit** are:

C_0 = 887.145737647938
C_1 = -201.377778592043
C_2 = 21.6869791448488
C_3 = -1.51505554823413
C_4 = .0592095029977134
C_5 = -.000974321373245196

3.1 Calculating Temperature in a Spreadsheet

The LE8200/LS4 software creates the spreadsheet compatible output in engineering units directly. The following. The following is a spreadsheet formula you can use to calculate a voltage reading into a natural log of resistance reading, is included here for information purposes only. This formula assumes that the voltage to be converted is at cell D12.

@LN(((2.5*9901)/@ROUND(D12,3))-9901)

The next formula will convert the natural log of the resistance readings into temperature readings(Celsius). This formula assumes that the natural log value to be converted is at cell F12 and that the coefficients are stored in the spreadsheet at locations B2 to B7 as shown in Fig 14.

+B2+F12*(B3+F12*(B4+F12*(B5+F12*(B6+(F12*B7)))))

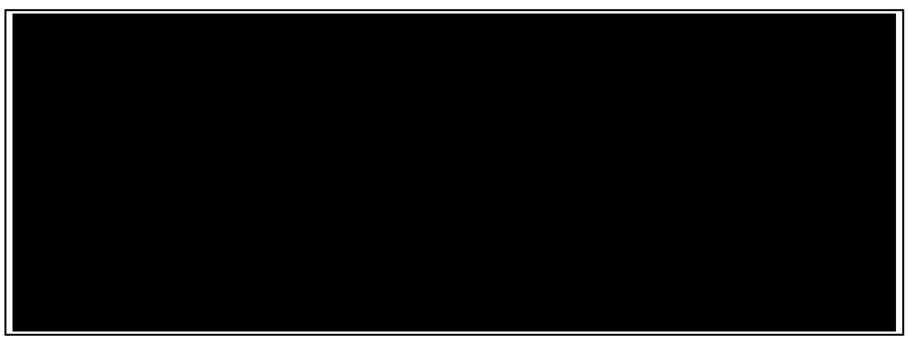

Fig. 14 Example Spreadsheet

3.2 Temperature Errors

The error produced from the datalogger's resolution and the curve fit is shown in Fig. 15. This error is separate from the interchangeable curve match tolerance error of the thermistor. Long lead lengths (over 100 - 200 meters) can also add errors to the temperature readings.

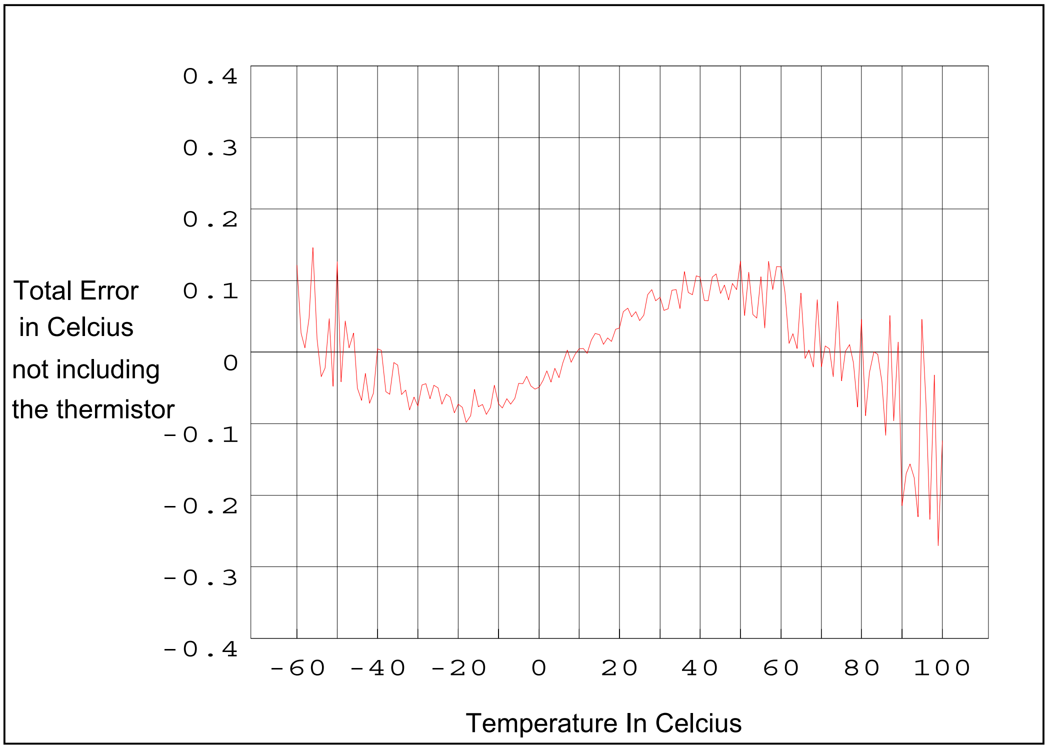

Fig. 15 Total Error in Celsius versus Temperature

3.3 Temperature versus TPX Probe Resistance Table

Temperature (Celsius)	Resistance (Ohms)	Ln(R)	Vout
-80	3684100	15.119537	0.007
-79	3370300	15.030512	0.007
-78	3085300	14.942159	0.008
-77	2826300	14.854479	0.009
-76	2590900	14.767516	0.010
-75	2376600	14.681181	0.010
-74	2181500	14.595523	0.011
-73	2003800	14.510556	0.012
-72	1841700	14.426200	0.014
-71	1693800	14.342485	0.015
-70	1558800	14.259427	0.016
-69	1435400	14.176954	0.017
-68	1322700	14.095186	0.019
-67	1219500	14.013951	0.020
-66	1125100	13.933382	0.022
-65	1038600	13.853384	0.024
-64	959350	13.774011	0.026
-63	886650	13.695206	0.028
-62	819950	13.616999	0.030
-61	758700	13.539362	0.033
-60	702450	13.462330	0.035
-59	650700	13.385804	0.038
-58	603150	13.309921	0.041
-57	559350	13.234531	0.044
-56	519000	13.159659	0.047
-55	481870	13.085430	0.051
-54	447620	13.011700	0.055
-53	416020	12.938489	0.059
-52	386860	12.865818	0.063
-51	359930	12.793665	0.068
-50	335050	12.722035	0.072
-49	312050	12.650919	0.078
-48	290770	12.580288	0.083
-47	271090	12.510206	0.089
-46	252860	12.440591	0.095
-45	235970	12.371460	0.102
-44	220320	12.302836	0.109
-43	205800	12.234660	0.116
-42	192340	12.167020	0.124
-41	179840	12.099823	0.132

Temperature (Celsius)	Resistance (Ohms)	Ln(R)	Vout
-40	168230	12.033087	0.140
-39	157440	11.966800	0.149
-38	147410	11.900973	0.159
-37	138090	11.835661	0.169
-36	129410	11.770741	0.179
-35	121330	11.706269	0.190
-34	113810	11.642286	0.202
-33	106880	11.579462	0.214
-32	100260	11.515522	0.227
-31	94165	11.452804	0.240
-30	88480	11.390532	0.254
-29	83170	11.328642	0.268
-28	78215	11.267217	0.283
-27	73580	11.206129	0.299
-26	69250	11.145478	0.315
-25	65205	11.085291	0.332
-24	61420	11.025491	0.350
-23	57875	10.966041	0.368
-22	54555	10.906965	0.387
-21	51450	10.848366	0.407
-20	48536	10.790061	0.427
-19	45807	10.732192	0.448
-18	43247	10.674683	0.470
-17	40845	10.617540	0.492
-16	38592	10.560800	0.514
-15	36476	10.504410	0.538
-14	34489	10.448396	0.562
-13	32621	10.392712	0.587
-12	30866	10.337411	0.612
-11	29216	10.282472	0.637
-10	27663	10.227851	0.664
-9	26202	10.173591	0.691
-8	24827	10.119687	0.718
-7	23532	10.066116	0.746
-6	22313	10.012925	0.774
-5	21163	9.960010	0.802
-4	20079	9.907430	0.831
-3	19058	9.855242	0.860
-2	18094	9.803336	0.890
-1	17184	9.751734	0.920

Temperature (Celsius)	Resistance (Ohms)	Ln(R)	Vout
0	16325	9.700453	0.950
1	15515	9.649563	0.980
2	14749	9.598931	1.010
3	14026	9.548668	1.041
4	13342	9.498672	1.071
5	12696	9.449042	1.102
6	12085	9.399720	1.132
7	11506	9.350624	1.162
8	10959	9.301916	1.193
9	10441	9.253496	1.223
10	9949.5	9.205278	1.253
11	9485.0	9.157467	1.283
12	9044.5	9.109912	1.313
13	8627.0	9.062652	1.342
14	8231.0	9.015663	1.371
15	7855.5	8.968969	1.400
16	7499.0	8.922525	1.429
17	7161.0	8.876405	1.457
18	6840.0	8.830543	1.485
19	6535.8	8.785050	1.512
20	6246.0	8.739697	1.539
21	5971.0	8.694670	1.565
22	5709.5	8.649887	1.591
23	5461.0	8.605387	1.617
24	5225.0	8.561210	1.642
25	5000.0	8.517193	1.667
26	4786.1	8.473471	1.691
27	4582.5	8.430000	1.714
28	4388.7	8.386788	1.737
29	4204.2	8.343839	1.760
30	4028.4	8.301125	1.782
31	3860.9	8.258656	1.804
32	3701.3	8.216439	1.825
33	3549.2	8.174478	1.845
34	3404.1	8.132736	1.865
35	3265.7	8.091229	1.885
36	3133.8	8.050002	1.903
37	3007.8	8.008964	1.922
38	2887.6	7.968181	1.940
39	2772.8	7.927613	1.957
40	2663.2	7.887284	1.974
41	2558.5	7.847176	1.991

Temperature (Celsius)	Resistance (Ohms)	Ln(R)	Vout
42	2458.5	7.807307	2.007
43	2362.9	7.767645	2.022
44	2271.6	7.728240	2.037
45	2184.2	7.689005	2.052
46	2100.7	7.650026	2.066
47	2020.8	7.611249	2.080
48	1944.4	7.572709	2.093
49	1871.2	7.534335	2.106
50	1801.2	7.496208	2.118
51	1734.2	7.458301	2.131
52	1670.0	7.420579	2.142
53	1608.5	7.383057	2.154
54	1549.5	7.345688	2.165
55	1493.1	7.308610	2.175
56	1439.0	7.271704	2.186
57	1387.1	7.234971	2.195
58	1337.4	7.198483	2.205
59	1289.7	7.162165	2.214
60	1243.9	7.126007	2.223
61	1200.0	7.090077	2.232
62	1157.9	7.054363	2.241
63	1117.5	7.018849	2.249
64	1078.6	6.983419	2.257
65	1041.4	6.948321	2.264
66	1005.6	6.913340	2.272
67	970.70	6.878017	2.279
68	938.10	6.843857	2.286
69	906.35	6.809426	2.292
70	875.80	6.775138	2.299
71	846.40	6.740992	2.305
72	818.10	6.706985	2.311
73	790.95	6.673235	2.317
74	764.80	6.639614	2.322
75	739.65	6.606177	2.328
76	715.50	6.572982	2.333
77	692.25	6.539947	2.338
78	669.85	6.507054	2.343
79	648.30	6.474354	2.348
80	627.60	6.441903	2.352
81	607.60	6.409517	2.357
82	588.35	6.377322	2.361
83	569.85	6.345373	2.365

Temperature (Celsius)	Resistance (Ohms)	Ln(R)	Vout
84	552.00	6.313548	2.369
85	534.85	6.281986	2.373
86	518.25	6.250458	2.377
87	502.30	6.219198	2.380
88	486.89	6.188038	2.384
89	472.04	6.157064	2.387
90	457.72	6.126258	2.391
91	443.91	6.095622	2.394
92	430.57	6.065110	2.397
93	417.71	6.034787	2.400
94	405.30	6.004628	2.403
95	393.32	5.974624	2.405
96	381.75	5.944766	2.408
97	370.58	5.915069	2.411
98	359.79	5.885521	2.413
99	349.36	5.856103	2.416
100	339.30	5.826885	2.418
101	329.56	5.797758	2.420
102	320.17	5.768852	2.422
103	311.07	5.740018	2.425
104	302.30	5.711420	2.427
105	293.79	5.682865	2.429
106	285.58	5.654522	2.431
107	277.65	5.626361	2.432
108	269.95	5.598237	2.434
109	262.51	5.570289	2.436
110	255.30	5.542439	2.438
111	248.35	5.514839	2.439
112	241.60	5.487283	2.441
113	235.08	5.459926	2.443
114	228.75	5.432630	2.444
115	222.62	5.405466	2.446
116	216.69	5.378468	2.447
117	210.97	5.351716	2.448
118	205.39	5.324911	2.450
119	200.00	5.298317	2.451
120	194.78	5.271871	2.452
121	189.72	5.245549	2.453
122	184.82	5.219382	2.455
123	180.04	5.193179	2.456
124	175.45	5.167354	2.457
125	170.96	5.141430	2.458

Temperature (Celsius)	Resistance (Ohms)	Ln(R)	Vout
126	166.61	5.115656	2.459
127	162.42	5.090186	2.460
128	158.33	5.064681	2.461
129	154.36	5.039288	2.462
130	150.52	5.014096	2.463
131	146.79	4.989003	2.464
132	143.17	4.964033	2.465
133	139.64	4.939068	2.466
134	136.22	4.914271	2.466
135	132.91	4.889672	2.467
136	129.69	4.865147	2.468
137	126.56	4.840717	2.469
138	123.52	4.816403	2.469
139	120.57	4.792230	2.470
140	117.68	4.767969	2.471
141	114.91	4.744149	2.472
142	112.20	4.720283	2.472
143	109.56	4.696472	2.473
144	107.01	4.672922	2.474
145	104.50	4.649187	2.474
146	102.08	4.625757	2.475
147	99.720	4.602366	2.475
148	97.435	4.579185	2.476
149	95.215	4.556137	2.476
150	93.040	4.533030	2.477

4.0 IPT Specifications

Parameter	Min.	Typical	Max.	Units
Input Range	0.0		5	MΩ
Output Voltage	0.0		2.5	Volts
Input Resistance***		9901	10000	Ohms
Input Resistance Temperature coeff.		25		ppm/°C
Operating Temperature	-60	25	100	°C
Turn On Delay	35	60	∞	ms

4.1 TPX Specifications

Parameter	Min.	Typical	Max.	Units
Operating Range	-80		150	°C
R-T Interchange ability(0-70°C)		±0.2		°C
Resistance @ 25°C		5000		Ohms
Dissipation Constant in Air*		1		mw/°C
Time Constant in Air**		20	∞	seconds

4.2 TP10K-X Specifications

Parameter	Min.	Typical	Max.	Units
Operating Range	-80		150	°C
R-T Interchange ability(0-70°C)		±0.2		°C
Resistance @ 25°C		5000		Ohms
Dissipation Constant in Air*		1		mw/°C
Output Resistance Across Green and Black Wires***		9901	10000	Ohms
Output Resistance Temperature coeff.		25		ppm/°C
Time Constant in Air**		20	∞	seconds

*The dissipation constant is the amount of power in militates which will raise the thermistor 1°C above it's surroundings.
**Time constant is the amount of time required in seconds for the thermistor to change its own temperature 63% of the way from it's original value to the value impressed upon it in a step change.
*** Typical is when connected to logger. Maximum is when not connected to logger.