Application Note A69 - ZERO Temp. Comp. Thermopile Trouble Shooting & Theory of Operation

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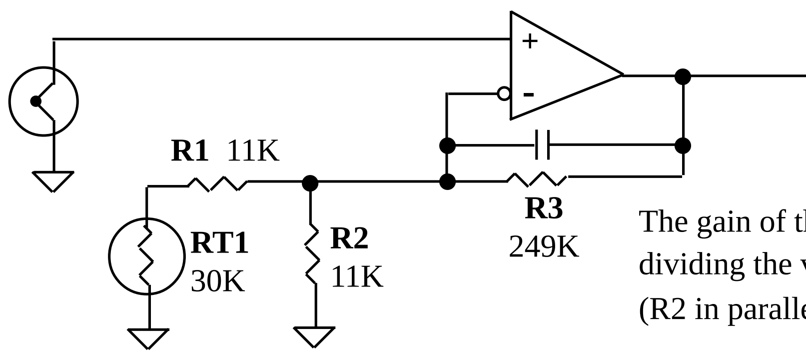
The **thermopile detector** is ZERO temperature compensated by an operational amplifier with its' gain controlled by a **30K @25°C** NTC **thermistor** (see table below). The Model **2015BMC-F** is an example of a thermopile detector with NTC thermistor temperature compensation. With ZERO (N_2)gas in the cell, the ideal peak to peak output of the pre-amplifier should not change as temperature changes. The reality is that the detector's responsivity (about **-0.4%/°C**) decreases as temperature increases. To compensate for this we change the gain of the pre-amp by using a 30K at 25°C thermistor in the preamp. At 0°C the thermistor is about 95K instead of 30K at 25°C and at 50°C it is about 11K.With the standard values of R3 = 249K, R1 = 11K and R2 = 11K, the thermistor decreases the gain of the preamp from about **28** at 25°C to about **25** at **0°C**. It increases the gain to about **33** at **50°C**. The thermistor has a ±5% tolerance. See the chart below for the effect of these tolerances.

Thermopile Detector: Its peak to peak output decreases as temperature increases by about **-0.4% per °C** with nitrogen in the gas cell. See page 4 for theory of operation & block diagram.



Peak to peak signal output **decreases** in amplitude as the **level of CO_2 increases**.

The gain of this amplifier is calculated by dividing the value of R3 ($\mathbf{R_f}$) by the value of (R2 in parallel with R1 + RT1) = ($\mathbf{R_{in}}$).

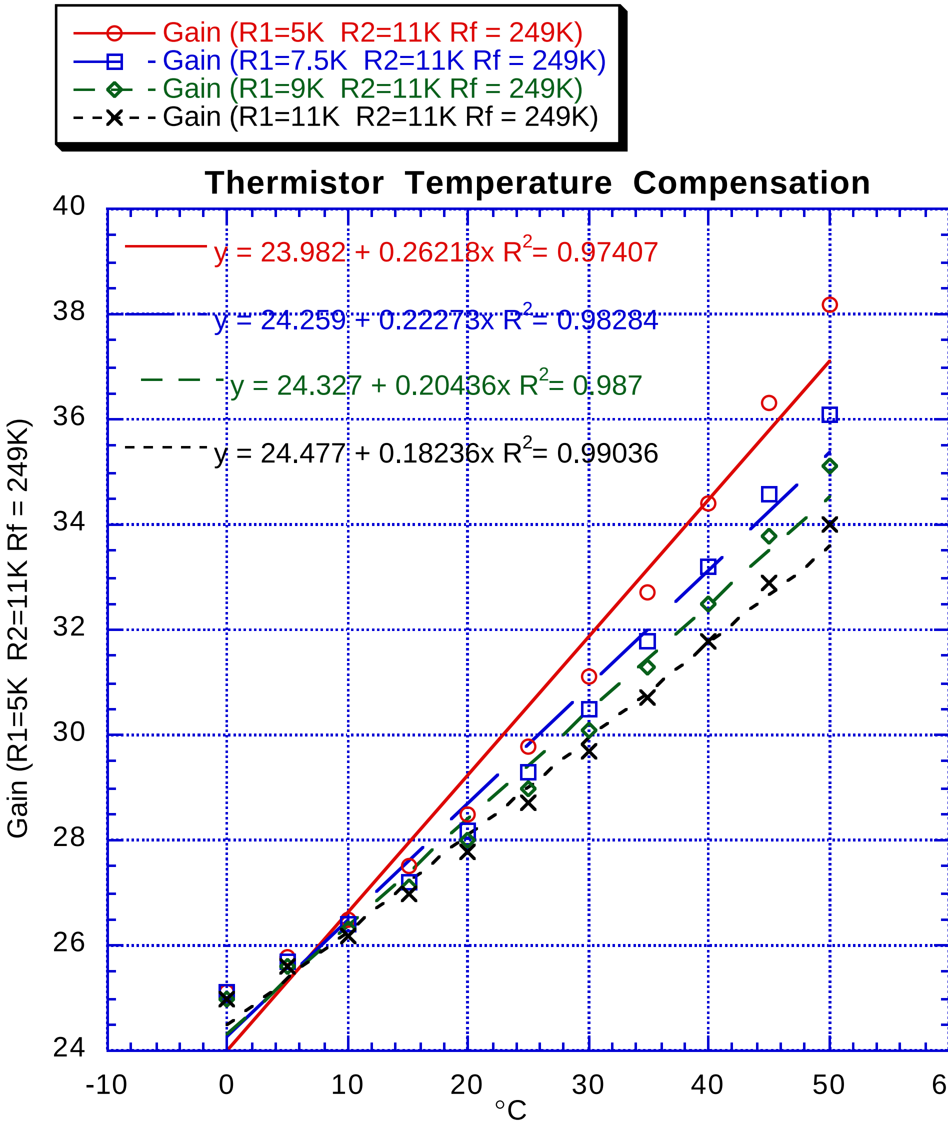
Gain = Rf/Rin	Rf= 249K	Rf MAX	Rf MIN	11000	11110	10890
DALE®Thermistor:	8C3002-5	251490	246510	**11000**	11110	10890
curve = 8		Rt MAX@ 25°C	Rt MIN@ 25°C			
30K±5%@25°C		31500	28500			
Temp °C	Rt/R25°C			Minimum Gain	Maximum Gain	Average Gain
0	3.166	99729	90231	24.0	25.6	24.8
5	2.481	78152	70709	24.5	26.2	25.3
10	1.958	61677	55803	25.0	26.9	25.9
15	1.556	49014	44346	25.6	27.6	26.6
20	1.243	39155	35426	26.2	28.5	27.4
25	1.000	31500	28500	27.0	29.5	28.2
30	0.809	25484	23057	27.8	30.5	29.1
35	0.658	20727	18753	28.6	31.6	30.1
40	0.538	16956	15342	29.4	32.7	31.1
45	0.443	13945	12617	30.3	33.8	32.1
50	0.366	11520	10422	31.2	34.9	33.0

This chart shows how the **tolerances** on the components effect the pre-amp gain. The thermistor has a **±5%** tolerance and the resistors have a **±1%** tolerance.

Check the **thermistor** to make sure it is not **shorted** or **open**. If it is **shorted** you will obviously read **0 ohms** across it. If it is **open** you will read the sum of R1 and R2 or about **22K** ohms. It should read about 30K in parallel with 22K or about **12.7K** ohms at **25°C** or **77°F**. At 20°C, per the above chart, it should read about 1.243 times higher resistance or about 37.29 K in parallel with the 22K or about **13.84 K** ohms **at 20°C** or **68°F**. °F = 9/5 (°C) + 32 .

If the 0 to 1 volt output goes **up-scale** as **temperature increases** then the detector is **under compensated**. The gain of the preamp needs to increase more as temperature increases to keep the peak to peak preamp signal from decreasing too much as temperature increases. You would do this by decreasing the value of $\mathbf{R_{in}}$. R2 should not be changed. You decrease **R1** to increase the gain and increase compensation. See the charts on Page 2 for the effects of different values of R1 on the gain.

 e-mail: **bpynenb@goldrush.com**
3463 Double Springs Road • Valley Springs, CA 95252 • (209) 754-0707 • FAX (209) 754-0104 •



R1 = 5K R2 = 11K RF = 249K

°C	Thermistor	Thermistor +R1	R2//Rt+R1	Gain
0	94980	99980	9910	**25.1**
5	74430	79430	9662	**25.8**
10	58740	63740	9381	**26.5**
15	46680	51680	9070	**27.5**
20	37290	42290	8729	**28.5**
25	30000	35000	8370	**29.8**
30	24270	29270	7995	**31.1**
35	19740	24740	7614	**32.7**
40	16149	21149	7236	**34.4**
45	13281	18281	6868	**36.3**
50	10971	15971	6514	**38.2**

R1 = 7.5K R2 = 11K RF = 249K

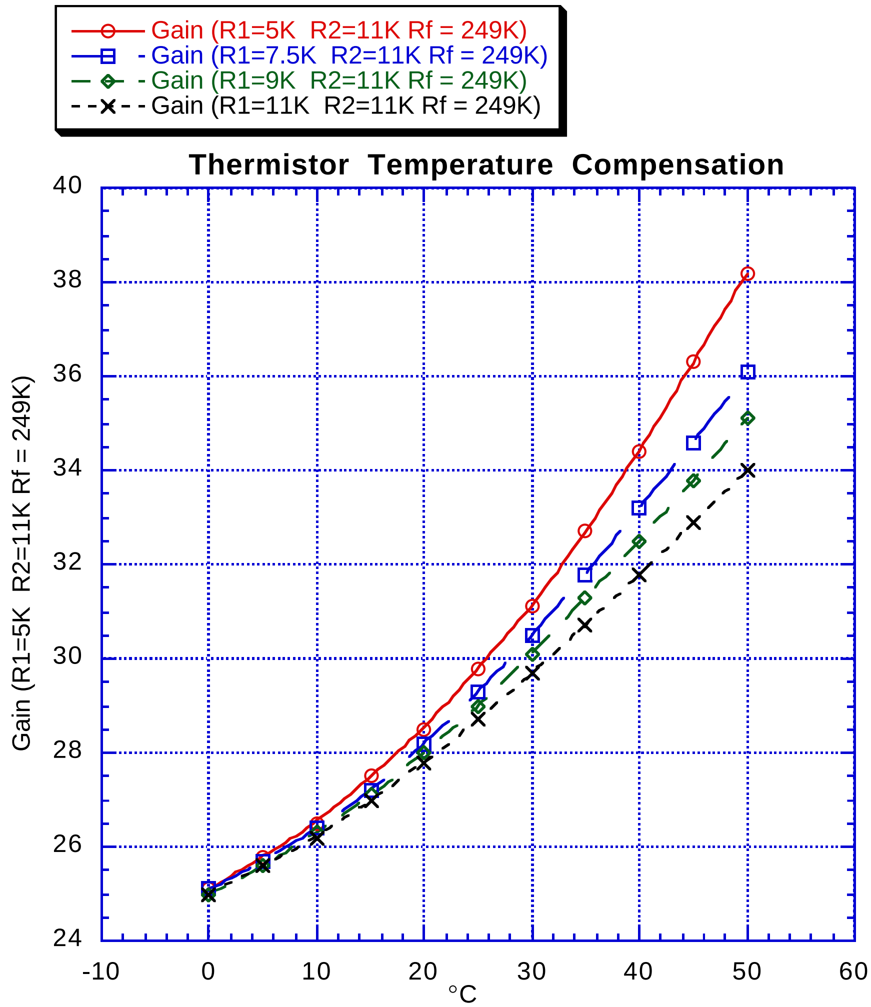
°C	Thermistor	Thermistor +R1	R2//Rt+R1	Gain
0	94980	102480	9934	**25.1**
5	74430	81930	9698	**25.7**
10	58740	66240	9433	**26.4**
15	46680	54180	9144	**27.2**
20	37290	44790	8831	**28.2**
25	30000	37500	8505	**29.3**
30	24270	31770	8171	**30.5**
35	19740	27240	7836	**31.8**
40	16149	23649	7508	**33.2**
45	13281	20781	7193	**34.6**
50	10971	18471	6894	**36.1**

R1 = 9K R2 = 11K RF = 249K

°C	Thermistor	Thermistor +R1	R2//Rt+R1	Gain
0	94980	103980	9948	**25.0**
5	74430	83430	9719	**25.6**
10	58740	67740	9463	**26.3**
15	46680	55680	9185	**27.1**
20	37290	46290	8888	**28.0**
25	30000	39000	8580	**29.0**
30	24270	33270	8267	**30.1**
35	19740	28740	7955	**31.3**
40	16149	25149	7653	**32.5**
45	13281	22281	7364	**33.8**
50	10971	19971	7093	**35.1**

R1 = 11K R2 = 11K RF = 249K

°C	Thermistor	Thermistor +R1	R2//Rt+R1	Gain
0	94980	105980	9966	**25.0**
5	74430	85430	9745	**25.6**
10	58740	69740	9501	**26.2**
15	46680	57680	9238	**27.0**
20	37290	48290	8959	**27.8**
25	30000	41000	8673	**28.7**
30	24270	35270	8385	**29.7**
35	19740	30740	8101	**30.7**
40	16149	27149	7828	**31.8**
45	13281	24281	7570	**32.9**
50	10971	21971	7330	**34.0**



The specification for temperature compensation is that the signal output will not vary more than 0.5% of full scale per degree C. That means a **0 to 1 volt output** should vary less than **5 millivolts** per degree C with ZERO gas in the cell. A **0 to 5 volt output** should vary less than **25 millivolts** per degree C with ZERO gas in the cell. A **0 to 10 volt output** should vary less than **50 millivolts** per degree C with ZERO gas in the cell.

As you can see from the above graph and the graph on page 2, the thermistor compensation is not linear. It compensates more at the higher temperatures. This will cause some units to be slightly **over-compensated** (0 to 1 volt output goes **down-scale** as **temperature increases**) from **25 to 50°C** and more closely compensated from **0 to 25°C**.

Page 4 shows how carbon dioxide absorbs the infra-red energy that the bandpass filter passes through to the detector. The detectors' peak to peak output with nitrogen is at a maximum. The full scale concentration of CO_2 should attenuate this peak to peak level from about 10% to about 40% depending upon the gas cell path length and filter tolerances. This fractional attenuation is converted into the 0 to 1 volt output where 1 volt equals the full scale attenuation and 0 volts equals no attenuation. This is why the peak to peak level needs to be temperature compensated to keep the output relatively stable (less than 0.5% of full scale per °C) as ambient temperature changes.

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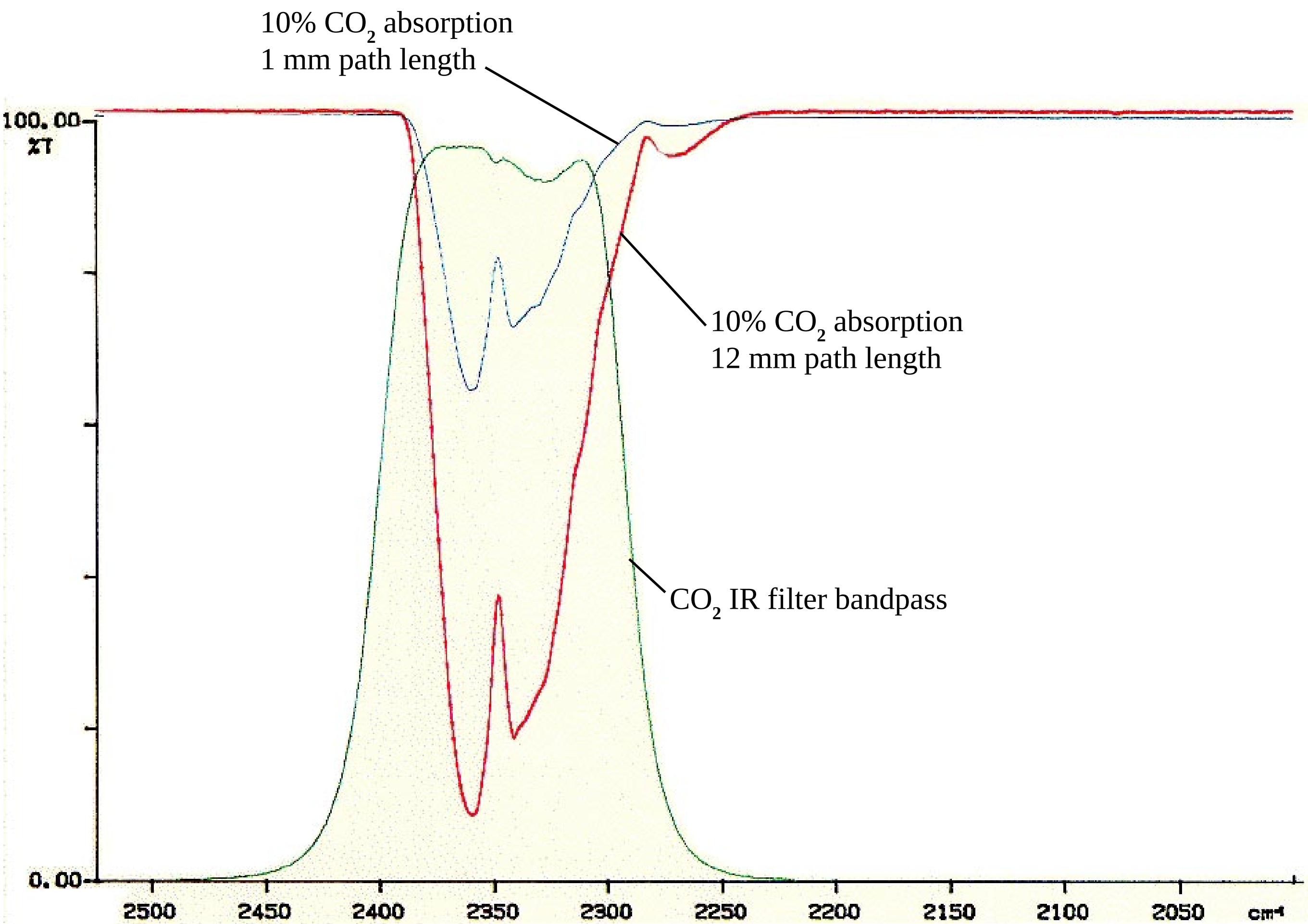
NDIR Theory of Operation



The reciprocal of the wavelength in centimeters know as the **Kayser wave number**