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Research Article

OP-AMP BASED INVERTING AMPLIFIER FOR GAIN LINEARIZATION OF NTC THERMISTOR CHARACTERISTICS

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ABSTRACT

NTC thermistors are commonly used for measurement of temperature due to their convenient shape, size, ruggedness and higher order of sensitivity. Thermistors relatively large resistance change per degree change in temperature makes it an obvious choice as a temperature transducer. A typical industrial thermistor with 2000 ohms resistance of 25^0C and a temperature coefficient of 3.9% per degree centigrade will exhibit a resistance change of 78 ohms per degree centigrade. In this paper, the author develops an analog technique and tested over a wide range of temperatures from 300^0K to 372^0K.The author develops a scheme using single thermistor for response linearization. The Taylor's series has been used to linearize the gain characteristic of the modified bridge circuit. The simulation and experimental results obtained thus is independent of the specifications of the thermistor.

INTRODUCTION

Most widely used semiconductor temperature sensing elements are thermistors. Their measuring range is typically between -50^0C to 300^0C, Although some designs have been developed by J. P. Bentley [2] for temperature in the low cryogenic range. The basic resistance versus temperature characteristic of a thermistor at zero power is expressed as

$$R_{T1=} R_{T0}e^{b((1/T1)-(1/T0))} \quad (1)$$

Where

R_{T1} = zero power resistance at measured absolute temperature T_1

R_{T0} = zero power resistance at measured absolute temperature T_0, usually T_0 is equal to 300^0K

Typical value of b is in between 3000 to 4500^0K, the value of zero power resistance at 300^0K can be between 500 ohms and above 10M ohms. These elements have high sensitivity, particularly between -50^0C and 100^0C. Thermistors are limited to temperature ranges between -50^0C and 300^0C. Positive Temperature Coefficient (PTC) thermistors are made from silicon and the resistance of a typical element increases from 500 ohms (at 55^0C) to 1900 ohms (at 125^0C). Sufficient literatures available are Smith [3, 4], Candy [5], Becker [6], Scar and Setterinton [7], Sapoff and Oppenhein [8], Brauer and Fenner [9], Cirker and Lobi [10], Prudenziate [11], and Hyde [12, 13] are available giving their theory, manufacturing process, properties and applications. In the early linearizing schemes, the linearizing network invariably incorporated a low value resistance in parallel with the thermistor. This reduces the sensitivity but increases the linearity i.e. the output voltage from the network is linear over a narrow temperature range. Linearization of thermistor-resistance temperature characteristics using active circuitry was developed by Chakraworty, R. K. and Slatter, K [14]. The value of fixed resistance was selected such that second and higher derivatives of the Taylor's Series expansion of resulting output voltage of the network vanished at a desired temperature. NTC thermistors have advantage of small physical size, low cost, ruggedness, and a large temperature coefficient. One of the main problems encountered with the thermistors in their highly non-linear response characteristic throughout their operating range. A sharp exponential decay in resistance of NTC element is observed with increase in temperature as shown in the Fig. 1(a) for a single thermistor and Fig. 1(b) for three thermistors.

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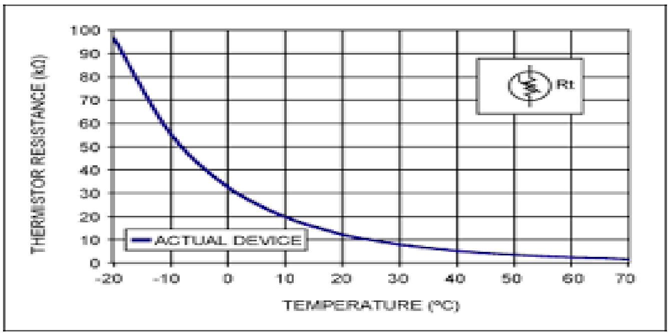

Fig. 1(a) Variation of resistance of a single NTC Thermistor with temperature

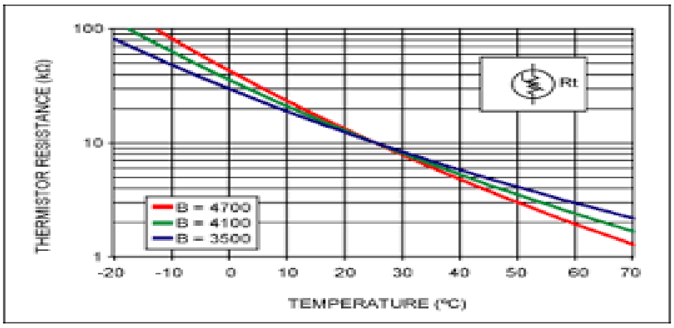

Fig. 1(b) Variation of resistance of three NTC Thermistors with temperature

Temperature Measurement Range

The range of temperature measured by the thermistor for common purposes is specified for stable operation, special thermistors from -50^{0}C to 300^{0}C. This however, compressed for stable operation, special thermistors from Al_2O_3 have been formed to cover a range on the high temperature side 800^{0}C to 1100^{0}C. Comparison in the range on the upper side is necessary for the possible physical changes at high temperatures. The lower side of the range is fixed by the increased resistance, which should be matched with the measuring circuit.

NTC Thermistors

NTC Thermistors are extensively used for measurement and control applications as they exhibit large variation of resistance over a wide range of temperatures. Semi-conductors usually have a high negative temperature coefficient and temperature is increased from 0 to 300^{0}C, thermistor resistance decreases by a factor of thousands. The most common type of NTC thermistor are manufactured by mixing oxides of iron group of transition metal elements like Cr, Mn, Fe, Co and Ni. The resistance of NTC thermistors decreases exponentially with increase in temperature. Owing to the negative temperature coefficient, an increase in temperature may result in an increase in the current flowing in the thermistor and hence an increase in the power dissipated as heat. Precautions must therefore be taken to ensure that the self-heating is kept negligibly small. The resistance versus temperature of a NTC thermistor is shown in Fig. 1.

PTC Thermistor

Positive Temperature Coefficient thermistors are mainly used as protective elements in electrical machinery particularly of the windings as in transformers and motors. These are usually made from titanate of Barium, Lead and Strontium. Their resistance temperature characteristics are somewhat similar to the current-voltage characteristics of a forward biased silicon diode. Up to a certain temperature, often referred to a reference temperature, the resistance increases very slowly but after that temperature, the increase is very rapid. The PTC thermistor is connected in series with the winding of the machine such that after a reference temperature is reached, the high resistance drops the current to such a low value and the machine effectively becomes off. The resistance-temperature characteristic of a PTC thermistor is shown in Fig. 2.

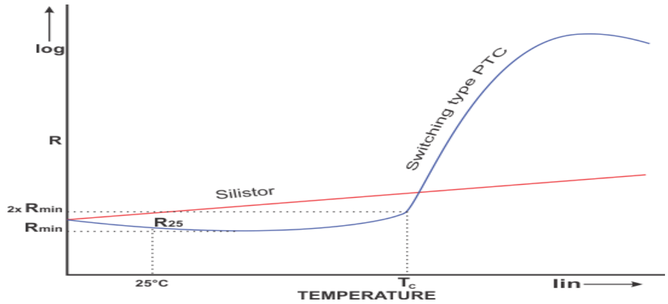

Fig 2 Variation of resistance of a PTC thermistor with temperature

Voltage-Current Characteristics of NTC Thermistor

If the current and voltage are sufficiently small then the temperature rise by the thermistor bead is appreciably low. Ohm's law is followed and the curve starts out in a straight line from the origin as shown in Fig. 3. For higher current and voltages, however the temperature of the bead is increased. For further increase in current, the resistance of the bead is decreases, and the voltage across it is less than if resistance remains constant. The curve, therefore droops to the right of the initial straight line projection. At a particular value of current causes a decrease of resistance of exactly the same proportion and the voltage remains constant. This current gives the peak value of the curve. A still higher currents, the resistance decreases more rapidly than the current increases and the characteristics exhibits a region of negative resistance as shown in Fig. 3.

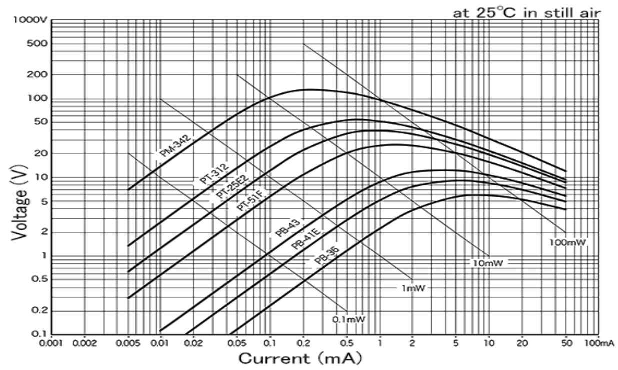

Fig 3 Voltage and Current characteristics of NTC thermistor

Factors affecting the Linearity of the thermistor

The resistance of the NTC thermistor decay exponentially with its temperature just like discharge of capacitor. The relationship of resistance against the temperature is already expressed in equation (1). In this equation, the value of 'b' lies between 3000K and 4500K, and determined from resistance measurements at the ice point and at 50^{0}C. The cold resistance values from various types of thermistor range from 500 Ω to over 10ΩM at 250^{0}C.

Linearization of Thermistor Response using Analog Circuits

Linearizing Scheme

NTC Thermistors are often used in wide variety of temperature measuring applications due to their foremost inherent properties as high resistance and negative temperature co-efficient. The Output-input response of the thermistor is highly non-linear throughout .their operating range of temperature. As a result, the measurement is usually restricted to small range of temperature for which the relation shown in equation (1) is approximately linear. One way to expand the region of operation is to linearize the relationship with the aid of electronic circuits. Most of the researchers produce qualitative approach while a few are loaded with quantitative approach. Each one out of them claims advantage over the previously developed approach.

The author of this paper, developed one analog scheme, namely "Single Thermistor Active Bridge" which were analysed for gain linearization of the thermistor in the range 300K to 370K.

Mathematical Modelling of Single Thermistor Active Bridge for gain

Linearization

The resistance temperature relationship for thermistor shown in equation (1) as below

$R_{T1=} R_{T0}e^{b((1/T1)-(1/T0))}$

All the parameters shown in above equation have their usual meaning. Fig. 4 shows the Single Thermistor Active Bridge and Fig. 5 shows an experimental circuit diagram in which currents in different branches of the bridge are marked.

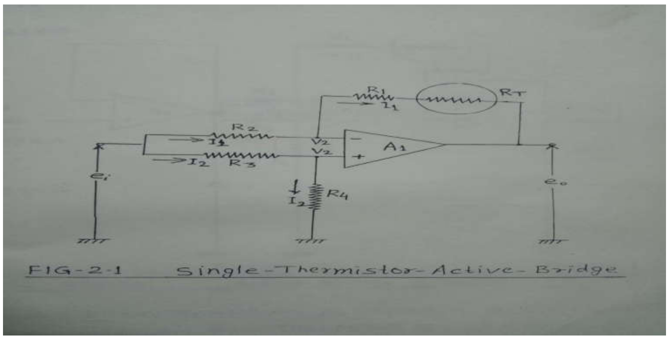

Fig 4 Single Thermistor Active Bridge

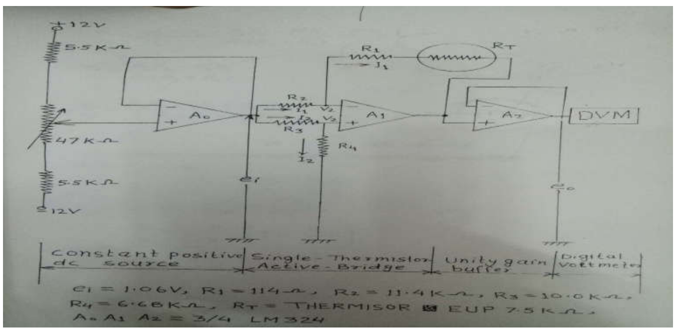

Fig 5 Experimental Circuit diagram of Single Thermistor Active Bridge

Now, from the Fig. 5, we get the final expression for gain i.e. the ratio of output voltage and input voltage as below

$$e_0/e_i=[(R_2/R_1)-(1+R_1R_2/R_2R_T)]/[(R_2/R_T)(1+R_3/R_4)] \quad (2)$$

The gain characteristics of NTC thermistor obtained in expression (2) above is to be needed to linearize.

RESULTS AND DISCUSSIONS

The experimental results were obtained and recorded in tabular form from Table I to Table V.

Variation of resistance of thermistor with temperature **Table I**

Temperature in ^{0}K	Resistance of thermistor in kΩ
300	7.50
305	6.49
310	5.58
315	5.02
320	4.10
325	3.25
330	2.75
335	2.24
340	1.90
345	1.65
350	1.50
355	1.23
360	1.10
365	1.00
370	0.89
375	0.81
380	0.74

Variation of output voltage with temperature for different values of delta **Table II**

Temp. in ^{0}K	O/P Voltage (e_0) for δ=0	O/P Voltage (e_0) for δ=0.1	O/P Voltage (e_0) for δ=0.2	O/P Voltage (e_0) for δ=0.3
300	0.000	0.000	0.000	0.000
308	0.100	0.094	0.078	0.055
316	0.178	0.150	0.125	0.095
324	0.228	0.195	0.162	0.125
332	0.265	0.245	0.190	0.153
340	0.305	0.252	0.215	0.175
348	0.330	0.285	0.230	0.185
356	0.355	0.294	0.245	0.192
364	0.365	0.310	0.255	0.205
372	0.380	0.325	0.265	0.215

Variation of gain with temperature for different values of delta **Table III**

Temp. in ^{0}K	Gain (KX) for δ=0	Gain (KX) for δ=0.1	Gain (KX) for δ=0.2	Gain (KX) for δ=0.3
300	0.000	0.000	0.000	0.000
308	0.095	0.086	0.070	0.053
316	0.165	0.142	0.115	0.091
324	0.220	0.189	0.155	0.120
332	0.255	0.216	0.183	0.136
340	0.295	0.245	0.205	0.152
348	0.310	0.268	0.219	0.161
356	0.330	0.280	0.235	0.173
364	0.348	0.293	0.246	0.198
372	0.357	0.305	0.256	0.207

Variation of % error of output voltage with temperature **Table IV**

Temp. in ^{0}K	% error of e_0 for δ=0.0	% error of e_0 for δ=0.1	% error of e_0 for δ=0.2	% error of e_0 for δ=0.3
300	0.000	0.000	0.000	0.000
308	2.000	7.787	8.210	6.895
316	4.495	5.263	4.850	6.000
324	2.195	5.540	3.750	5.385
332	0.375	2.675	4.145	5.250
340	2.657	3.110	4.186	4.720
348	2.156	3.214	3.462	3.845
356	2.456	2.725	3.285	3.625
364	1.897	2.288	4.651	4.440
372	2.432	0.968	3.435	5.236

Variation of TRC with temperature **Table V**

Temp. in ^{0}K	TRC (α) in % ^{0}K
300_0	-3.378
308	-3.200
316	-3.045
324	-2.890
332	-2.760
340	-2.650
348	-2.510
356	-2.345
364	-2.290
372	-2.220

CONCLUSIONS

- Tne scheme for gain linearization of NTC thermistor using Single-Thermistor-Active-Bridge has been analysed and tested successfully over a wide range of temperature from 300^0K to 372^0K without any trouble.
- The thermistor EUP7.5K has been used here for practical validation of the results.
- The results obtained by simulation are in good agreements with the experimental results obtained.
- A good linearity has been obtained over a wide range of temperature in two segments as obtained from the results.
- In the laboratory (EEE Department, NIT Jamshedpur), the facility available is limited to vary the temperature from 300^0K to 372^0K for the study of the influence of variation of temperature on the performance of thermistor.
- The study may be extended if the facilities available for variation of temperature for both sides i. e. in lower side as well as in upper side.

References

1. Broughton, M. B., "Analysis and Design of almost linear one thermistor temperature transducer." IEEE Trans. Instrumentation and Measurement, Vol. 23, No. 1, 1974.
2. Bentley, J. P., "Temperature Sensor characteristics and measurement system design.," *J. Phy, E., Sci, Instrumentation,* Vol. 17, pp. 320-328, 1984.
3. Smith, O. J. M., "Thermistor Part I, Static Characteristics." *Rev. Sci., Insrumentation*, Vol. 1, No. 4, pp. 344-350, April 1950.
4. Smith, O. J. M., "Thermistor Dynamic characteristics Part II " *Rev. Sci., Insrumentation*, Vol. 1, No. 4, pp. 351-356, April 1950.
5. Candy, C. J. N., "The specification of the properties of the Thermistor as a circuit element in a very low frequency system" Proc. IEEE, Vol. 103, pp. 398-418, Dec. 1954.
6. Becker, J. A., Green, C. B. and Pearson, G. L., "Properties and uses of Thermistor-Thermally sensitive resistor" *Trans. Elect. Engg*., Vol. 65, pp. 711-725, Nov. 1946.
7. Scarr, R. W. A. and Setterington, R. A., "Thermistors, Their theory, Manufacture and applications" Proc. IEEE, Vol. 107, pp. 395-409, 1960.
8. Sapoff, M. and Oppenheim, R. M., "Theory and application of self-excited thermistors" Proc. IEEE, Vol. 87, pp. 1292-1305., Oct. 1963.
9. Brauer, H. and Fenner, E., "PTC thermistor" Siemens Review, No. 3, pp. 95-101, March, 1965.
10. Cirker, W. and Lobi, H., "A new PTC thermistor-its features and applications as a liquid level monitor" Siemens Review, No. 9, pp.317-323, Sept., 1965.
11. Prudenziati, M., Taroin, A. and Zanarini, G., "Semiconductor sensors : I-Thermoresistive devices " IEEE Tranc. Ind. Electro. And Cont. Instrum. , Vol. 17, No. 6, pp.407-414, Nov. 1970.
12. Hyde, F. J., "Thermistors" Butterworth and Comp. (Pub.) Ltd., London, 1971.
13. Hyde, F. J., "Process/Industrial Instruments and Control Handbook" pp.424-425, 1972.
14. Chakraworty, R. K. and Slatter, K., "Linearization of Thermistor resistance temperature characteristic using active circuitry" *Rev. Sci. Instrum*., Vol. 38, No. 12, Dec 1977.

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