Thermal transducer Analysis

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1 author:

Adwait Borwankar
Vishwakarma Institute of Technology

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Adwait A. Borwankar, Ajay S. Ladkat, Manisha R. Mhetre

Abstract- Reliable operation of a transducer carries a great importance while choosing it for a particular application. This report characterizes the thermistor (10k), thermocouple and LM35 in detail. Thermal transducers are widely used in most of the industrial and scientific instrumentation. Transducers of different types and parameters are commercially available in the market by different manufacturers. Some parameters need to be checked before they use in a specific application. This paper includes comparison of thermistor, thermocouple and LM35 on such parameters which will be helpful for selecting proper transducer for specific application.

Key words:- Transducers, thermistors, thermocouple, LM35.

I. Introduction

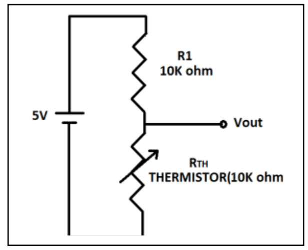
A transducer is a device that converts a signal in one form of energy/ physical quantity to another form of energy/ physical quantity. Here we are considering transducers which convert temperature into electrical parameter. In this document we analyze response of thermistor, thermocouple and LM35. This paper also includes the equations of its response and comparison based on various parameters such as linearity, errors, sensitivity. For this we have taken the voltage readings between room temperature 20°C to 150 °C. All readings were taken at same operating conditions, for all transducers simultaneously for avoiding errors in readings.

II. Thermistor-

Thermistors are essentially semiconductor devices which behave as thermal resistors having a high negative temperature coefficient of resistance. There are two types of thermistors available in market those are introduced below;

Negative temperature coefficient (NTC) thermistors are temperature sensors whose resistance decreases with increase in temperature. **Whereas Positive temperature coefficient (PTC)** thermistors are temperature sensors whose resistance increases with increase in temperature. In this paper we have considered NTC type thermistor for analysis purpose.

Figure 2.1 shows circuit arrangement for thermistor. It is the simplest circuit arrangement done by using voltage divider network. Voltage across thermistor is given by the equation shown below;



$$Vout = \frac{R_{TH}}{R1 + R_{TH}} \times 5V$$

Figure 2.1 shows the potential divider arrangement for thermistor (NTC)

Analysis of thermistor (NTC) for above mentioned range is given in Table 2.1.

TEMPERATURE (°C)	THERMISTER(10K) (mV)
20	2220
30	1700
40	1130
50	730
60	450
70	280
80	250
90	240
100	200
110	152
120	92
130	62
140	34
150	26

Table 2.1 voltage across thermistor for temperature range 20°C to 150°C.

As per the readings the Graph between temperature and voltage (mV) is drawn for further analysis purpose which is shown in figure 2.2

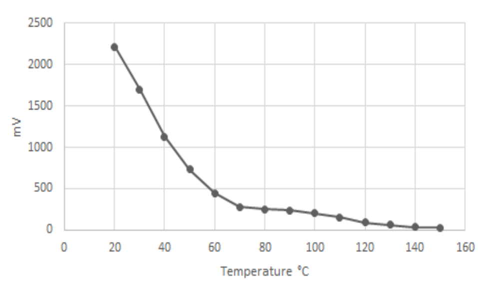


Figure 2.2 shows the response of thermistor

Sensitivity of thermistor in the range of 20°C to 60°C in around 40mV/°C while in the range of 60°C to 150°C it decreases up to 4.8mV/°C. Thermistors have high sensitivity which makes them suitable for various applications, but they exhibit a highly nonlinear resistance- temperature relationship which is exponential in nature.

III. Thermocouple

Thermocouples are based on the effect that the junction between two different metals produces a voltage which increases with temperature. There are many types of thermocouple such as type T, type J, type K, type E, etc. are available, which are divided on the basis of material used. This paper is gives the analysis of T type thermocouple which is given in below table.

TEMPERATURE (°C)	THERMOCOUPLE (mV)
20	0
30	0.5
40	1.2
50	2
60	2.8
70	3.7
80	4.6
90	5.5
100	6.3
110	7.3
120	8.2
130	9.1
140	10
150	11

Table 3.1 shows thermocouple voltage for temperature range 20°C to 150°C

As per the readings obtained the Graph between temperature and voltage (mV) is drawn for further analysis purpose which is shown in figure 3.1

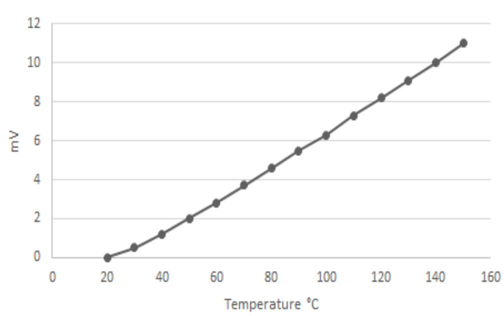


Figure 3.1 shows response of thermocouple

Equation of the graph (temperature – voltage (mV) of thermocouple) is calculated by using MATLAB which comes out to be approximately linear which is given by polynomial equation as below;

$$F(t) = 0.0004t^2 + 0.0444t - 1.1253$$

Here, F (t) --- Output voltage of thermocouple

t--- Temperature.

From this analysis we are able to find the Sensitivity of thermocouple in the range 20°c to 150°c which comes out to be 0.08 mV/°c.

IV. Semiconductor IC (LM 35)

The LM35 is a temperature sensor which requires input voltage as 4V to 20V whose output voltage is depends on the change in temperature. Figure 4.1 shows circuit arrangement for LM35. It is the simplest circuit arrangement which gives output voltage proportional to the Celsius temperature.

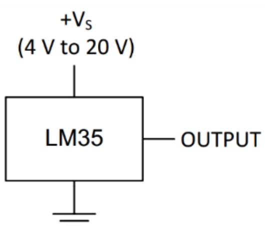


Figure 4.1 shows circuit arrangement for LM35

Analysis of LM35 for above range is given in Table 4.1.

TEMPERATURE (°C)	LM35 (mV)
20	201.2
30	302.3
40	401.7
50	503.4
60	602.5
70	700.1
80	804.3
90	901.6
100	1011
110	1103
120	1210
130	1321
140	1434
150	1572

Table 4.1 shows output voltage of LM35 for temperature range 20°C to 150°C

As per the readings the Graph between temperature and voltage (mV) is drawn for further analysis purpose which is shown in figure 4.2

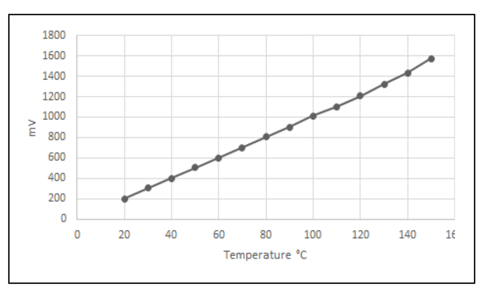


Figure 4.2 shows the response of LM35

Equation of the graph (temperature - mV) is calculated by using MATLAB which is comes out to be approximately linear relationship which is represented by polynomial equation,

$$F(x) = 0.0074x^2 + 9.0829x - 24.8104$$

Where, F (x) is output voltage of thermocouple
x is temperature

From the above analysis obtained sensitivity of LM35 for the range 20°c to 150°c is 10.17 mV/°c.

V. Results

From the above experimentation analysis we can talk about the linearity, power, and sensitivity of the thermal transducers. We can also talk about the ADC selection according to accuracy and resolution of transducer we required. Chart below describes the experimentation results of the analysis.

PARAMETERS	THERMISTOR	THERMOCOUPLE	LM 35
LINEARITY	LINEAR (20°C -60°C)	LINEAR (20°C -150°C)	LINEAR (20°C -150°C)
SENSITIVITY	(20°C -60°C) =40mV (60°C -150°C) =4.8mV	0.08 mV/°C	10.17 mV/°C
MAX. POWER	617.59 µW	-	300 µW
DIGITAL CIRCUIT COMPITIBILITY	Potential divider arrangement is required	Directly interfaced to controllers and ADC	Directly interfaced to controllers and ADC

Table 5.1 shows the experimentation results of thermal transducers.

VI. Conclusion

This analysis is use for the selection for the transducer of the particular temperature range. For the case of thermistor we can also select the particular range of operation according to the requirement of application and linearity we required in working. We observed that for general purpose application such as room temperature measurement with higher resolution in operation we can go for semiconductor type transducer with higher bits ADC's .Also for some special applications we can chose the thermal transducers according the sensitivity, linearity, and power requirement.

VII. References

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