RESEARCH OF PARAMETERS OF THE TERMISTOR CAR

P.S. KRASIN[1], N.A.VOLCHENKO[2]

[1]Oxford Brookes University,
Headington Campus Gipsy Lane, Oxford OX3 0BP UK,
e-mail: peter.krasin@mail.ru
[2]Kuban State Technological University,
2, Moskovskaya st. Krasnodar, Russian Federation, 350072

The article presents data about sensor called thermistor – resistor with a significant varying range of resistance with the temperature, which is widely used in automotive industry. Since the article investigates the problem of resistance change, thermistor was put in the standard "voltage divider" bridge circuit to conduct study. Polynomial equations are mostly used to identify the temperature. Overall thermistors have a large range of use in vehicle systems. Main purpose of the thermistor is to read the temperature from significant parts or units in the car such as an oil temperature, which is important information in engine development. It is used as part of a coolant temperature sensor which helps drivers to determine engine heating.
Key words: thermistor, temperature, automotive temperature sensor, electronic sensor, engine temperature, vehicle internal liquid temperature.

Thermistors, like platinum resistance thermometers, also use a change in resistance to measure temperature. However, the change in resistance is so different that, for all practical purposes, it is a totally different way of measuring temperature. The three differences are:

1. Resistance change is very large, not small.
2. Resistance usually decreases with temperature, instead of increasing.
3. Change in resistance is highly non-linear.

Thermistors are made from semiconductor material, and are really very low cost. They are quite widely used in automotive systems, and in this case, will be carefully housed in a suitable packaging to prevent damage. Figure 1 shows two automotive thermistors from Bosch. Most of the cost of these devices will be in the packaging and connectors. The one on the left is for air temperature measurement and on the right is for oil temperature:

Figure 1.1

Since the resistance decreases with higher temperatures, it is said to have a ‘negative temperature coefficient’, and may be called an NTC device. PTC thermistors do exist, but are more expensive, and have advantages in very few cases.

Table1 Given Data

Fixed resistor in Circuit	Calibration resistance	Calibration Temp		Beta
R_f in kOhms	R_o in kOhms	T_o in Celsius	T_o in Kelvin	
3.8	3.6	19	292.15	3990

Firstly known data should be added to MATLAB. This is done by following steps:

```
>> Rf=3.8;
>> Ro=3.6;
>> To=19;
>> Beta=3990;
```

We need to use a temperature in kelvin to find the value of R_t . To covert temperature from Celsius to Kelvin 273.15 must be added to the range. New array of temperature is produced by tying:

```
>> Tokelvin=To+273.15;
Tokelvin =   292
```

Since the range of temperature is given, set up the vector of Temperature values by typing:

```
>> T=linspace(0,100,11);
>> Tkelvin=T+273.15;
```

Find R_t value using the formula from TMA2:

```
>> Rt=Ro*exp(Beta*((1./Tkelvin)-(1/Tokelvin)));
```

Now graph is plotted:

```
>> plot(Rt,T)
>> plot(Rt,Tkelvin)
```

Finaly table is produced:

```
>> Table=[Rt,T,Tkelvin]
```

Table 1.1 Results for R_t at all temperature range

Resistance at any temperature	Temperature	
R_t in kOhms	T in Celsius	T in Kelvin
9.308	0	273.15
5.557	10	283.15
3.436	20	293.15
2.193	30	303.15
1.441	40	313.15
0.971	50	323.15
0.670	60	333.15
0.473	70	343.15
0.340	80	353.15
0.249	90	363.15
0.186	100	373.15

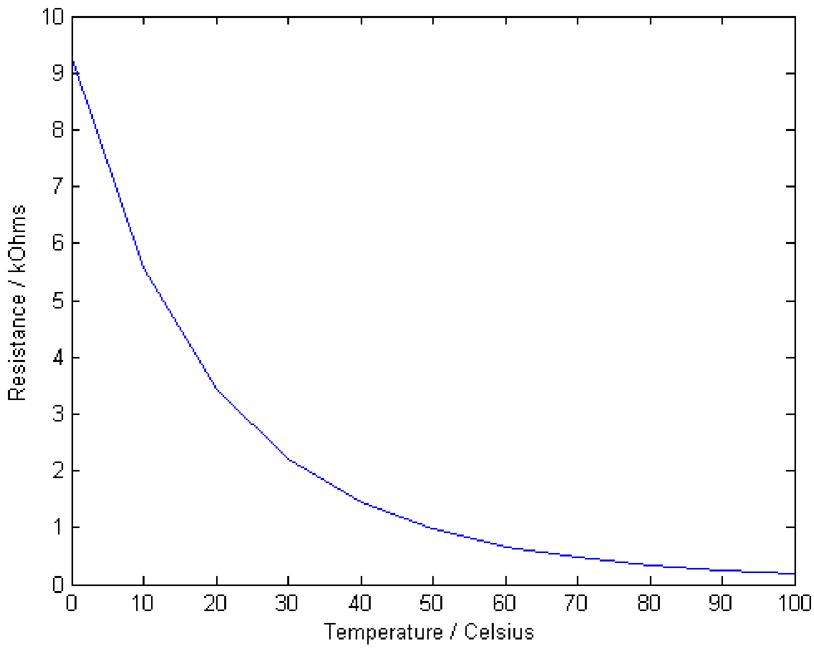

Figure 1.2 Resistance against Temperature, graph of the results given in Table 1.1

For the circuit above 5 Volt supply must be added to MATLAB:

>> Vs=5;

Find V_{out} using the formula [1]:

>> Vout=(Rt./(Rt+Rf))*Vs;

Graph is now plotted :

>> plot(Vout,T)

Table is produced :

>> Table=[T,Vout]

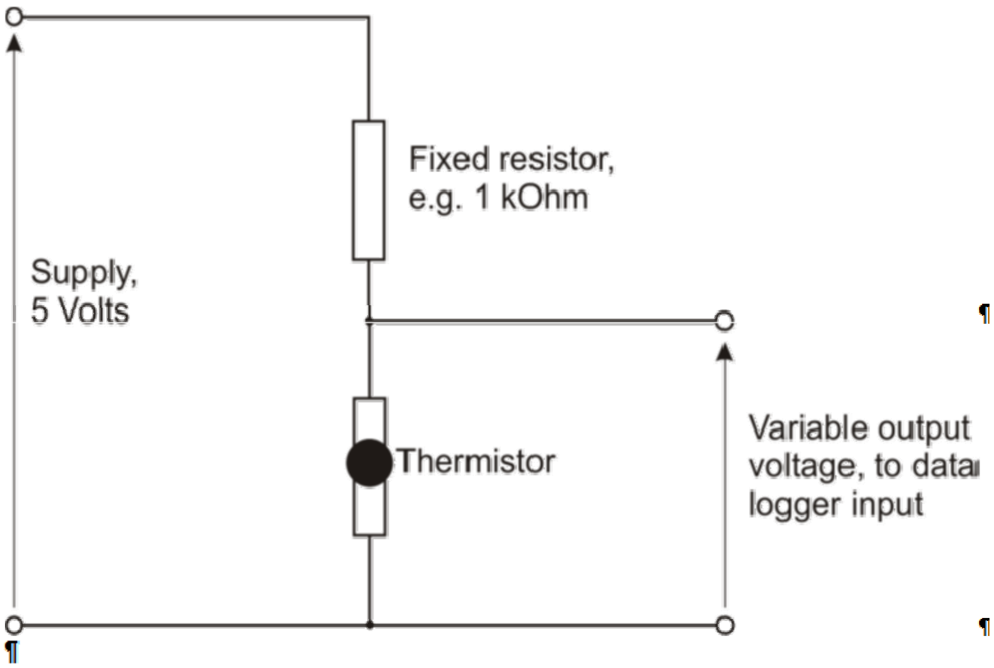

Figure 2.1 Circuit for the Thermistor [1]

Table 2.1 Results Output Voltage at all the Temperature Range

Temperature	Voltage Output
T in Celsius	V_{out} in Volts
0	3.551
10	2.969
20	2.374
30	1.830
40	1.374
50	1.018
60	0.750
70	0.553
80	0.411
90	0.308
100	0.233

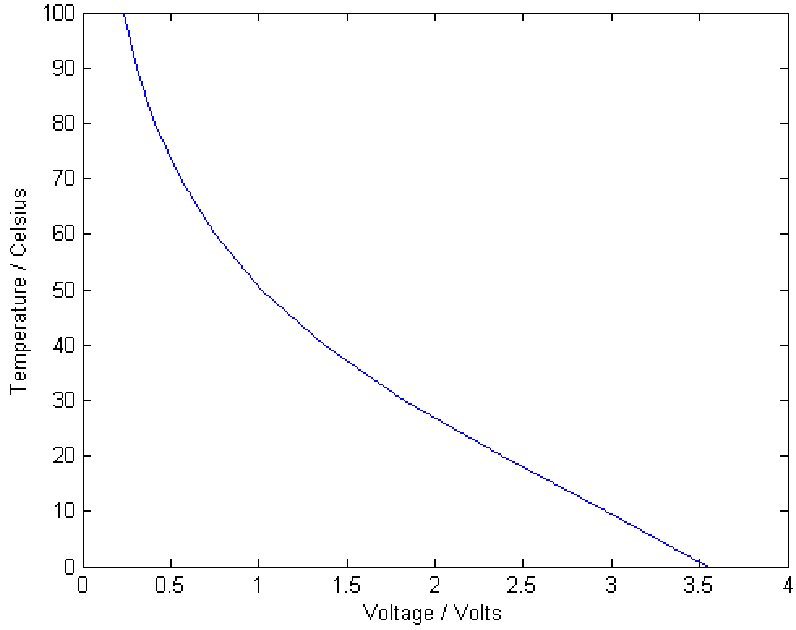

Figure 2.2 Temperatures against Voltage

To find the 3rd order polynomial MATLAB *polyfit* function is used:

>> PolyT3rd=polyfit(Vout,T,3)

Poly3rd = -4.9219 35.3311 -96.5291 116.4307

This means that 3rd order Polynomial:

$y = -4{,}9219x^3 + 35{,}331x^2 - 96{,}529x + 116{,}43$

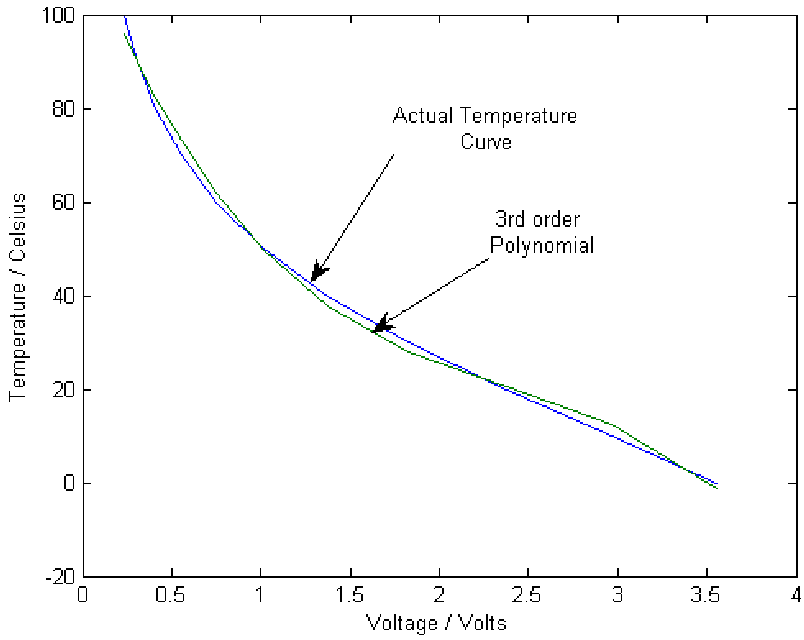

Figure 3 Polynomial 3rd order equation graph

To get the values of polynomial equation use the *polyval* function in MATLAB :

```
>> CalcT3rd=polyval(PolyT3rd,Vout);
```

Error in Celsius calculated using the following equation in MATLAB :

```
>> ErrorC=T-CalcT3rd;
```

Finaly percentage of full-scale-deflection produced :

```
>> fsd=(ErrorC/100)*100;
>> Table=[Vout,T,CalcT3rd,ErrorC,fsd]
```

Table 4 Calculations to find the linearity error of the thermistor of Table 2.1.

Voltage Output / Volts	Actual Temperature / Celsius	Temperature Calculated Using 3rd order Polynomial / Celsius	Error in Celsius	Error as a percentage of f.s.d / %
3.551	0	-1.207	1.207	1.207
2.969	10	12.456	-2.456	-2.456
2.374	20	20.535	-0.535	-0.535
1.830	30	27.942	2.058	2.058
1.374	40	37.720	2.280	2.280
1.018	50	49.595	0.405	0.405
0.750	60	61.839	-1.839	-1.839
0.553	70	72.998	-2.998	-2.998
0.411	80	82.391	-2.391	-2.391
0.308	90	89.923	0.077	0.077
0.233	100	95.799	4.201	4.201

To get the value of temperature at 1.8 Volts, *polyval* function used but the V_{out} value is set to 1.8:

```
>> CalcT1=polyval(PolyT3rd,1.8)
CalcT1 =   28.4295
```

Calculated temperature at 1,8 Volts using 3rd order Polynomial =   28.4295

There are two given formulas of resistance R_t and output Voltage V_{out}:

$$Rt = Ro * \exp\left(\beta\left(\frac{1}{T} - \frac{1}{To}\right)\right)$$

$$V_{out} = \frac{R_t}{R_t - R_f} * V_s$$

Developing both equations:

$$V_{out} = \frac{V_s * R_o * exp\left(\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)\right)}{R_o exp\left(\beta\left(\frac{1}{T} - \frac{1}{T_o}\right)\right) - R_f}$$

$$V_{out} * R_o * e^{\left(\frac{\beta}{T} - \frac{\beta}{T_o}\right)} - V_{out} * R_f - V_s * R_o * e^{\left(\frac{\beta}{T} - \frac{\beta}{T_o}\right)} = 0$$

$$e^{\left(\frac{\beta}{T} - \frac{\beta}{T_o}\right)} = \frac{V_{out} * R_f}{V_{out} * R_o - V_s * R_o}$$

Logarithm equation above:

$$\frac{\beta}{T} - \frac{\beta}{T_o} = \ln \frac{V_{out} * R_f}{V_{out} * R_o - V_s * R_o}$$

$$T = \frac{\beta}{\ln \frac{V_{out} * R_f}{V_{out} * R_o - V_s * R_o} + \frac{\beta}{T_o}}$$

Expression above is inserted in MATLAB to get the value of Temperature at 1.8 Volts:

```
>> T=Beta/(log(1.8*Rf/(1.8*Ro-Vs*Ro))+(Beta/To))
T = 19.0430 - 0.2856i
```

Comparing the answers it is noticeable that the last equation consists of complex number due to *Ln* function and less accurate rather than 3rd order Polynomial equation. However the Polynomial equation has an error as well.

To summarize, the main practical points with regard to thermistors are:

· Thermistors cannot normally be used above about 160 Celsius, whereas Thermo Couples can go up to about 1500 Celsius.

· At lower temperatures (typically −40 to 100 Celsius) thermistors are probably more accurate.

· Thermistors do not need any amplifying nor cold junction compensation.

Connecting them to data loggers is thus simpler and much cheaper.

· The active part of a thermistor is larger, so they do not respond so quickly to temperature changes: thus, we say that the 'dynamic response' of thermocouples is usually better.

· The calibration data must be provided, where it is available from standard references.

ИССЛЕДОВАНИЕ ПАРАМЕТРОВ ТЕРМИСТОРА АВТОМОБИЛЯ

П.С. КРАСИН[1], Н.А. ВОЛЬЧЕНКО[2]

[1]Университет Оксфорд Брукс,
Headington Campus Gipsy Lane, Oxford OX3 0BP UK,
e-mail: peter.krasin@mail.ru
[2] Кубанский государственный технологический университет,
350072, Российская Федерация, г. Краснодар, ул. Московская, 2

В статье представлены данные о сенсоре, который называется термистор – резистор со значительным диапазоном изменения сопротивление по отношению к температуре, данный сенсор широко используется в автомобильной индустрии. Так как статья затрагивает проблему изменения сопротивления в сенсоре, для изучения термистор был подключен в цепь стандартным методом «разделения напряжения». Полиномиальные уравнения были использованы для определения температуры. В целом термисторы могут использоваться в достаточно большой области автомобильных систем. Главная их задача заключается в том, что бы определять температуру главных деталей и узлов автомобиля таких как, например температура масла, данная информация очень важна для создания и доработки двигателя. Так же термистор используется как часть сенсора определяющего температуру двигателя, данные которого водитель может видеть для определения нагрева двигателя.

Ключевые слова: термистор, температура, автомобильный датчик температуры, электронный датчик, сенсор, температура двигателя, температура внутренних жидкостей автомобиля.