OPEN SOURCE DEVICE FOR NTC THERMISTOR CURVE REPRESENTATION

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Keywords: thermistor, open source, NTC, temperature, resistance, analog sensor, CSV logger, RT curve, Steinhart-Hart.

Abstract: *The paper represents a review of an open source testing platform, for NTC thermistors, that are to be used in different temperature monitoring applications. The NTC thermistors are analog, nonlinear, passive, electronic components that change their resistance according to temperature. The advantages of these widely used components for temperature monitoring, are the low price and availability on the market. The testing platform is comprised of an open source acquisition board with an adaptive shield, for storing the acquired data with a timestamp, on an SD-card, for later processing. A power resistor connected to an adjustable DC power supply, is used to act as a heater for the thermistor, in order to induce the desired temperature and thus resistance. From the datalogger CSV file, an NTC thermistor characteristics curve can be build in order to calculate the Steinhart-Hart coefficients, for mathematical expression of the resistance-temperature relation.*

1. INTRODUCTION

Most OEM electronic components manufacturers publish datasheets with the physical parameters of their products, to be available for consumers. In these cases, interfacing the components with the logic hardware and software is easy and comprehensive, but with the expense of higher costs of the original products. The difficulties, in the practical implementations, appear when aftermarket products are used, when no data over the component is available. The only solution in these cases is to experiment a theoretical and practical evaluation of the components in controlled conditions in order to obtain some useful characteristics data for later use.

In the NTC thermistor industry, the β (beta) parameter value and the Steinhart-Hart *A*,*B* and *C* coefficient values, are mostly used for describing the *RT* (resistance-temperature) relation curve [1]. This type of thermistors are nonlinear devices that change their resistance inversely proportional to the sensed temperature [2].

They are cheap, simple, robust and require minimal circuitry for physical interface with the logic hardware (require only a series resistor for output voltage read).

The only drawback of these components is the precision error, which can range from 0,2°C to 2ºC, according to the manufacturer and the materials used in its construction. Thus the software algorithm filtering, plays a decisive role most of the times, for accurate readings.

Although similar articles, regarding the thermistors, do approach code based calculus for the β or the Steinhart coefficients, unfortunately none of them presents a complete solution of *measuerement* (in order to find out the A, B and C Steinhart coefficients), *data acquisition* on SD memory and *representation* of the RT curve altogether [3]. In many articles, authors tend to use predefined values for either β or Steinhart coefficients, from datasheet tables, without experimentation, thus leading to misinterpreted results.

2. APPLICATION HARDWARE DESCRIPTION

In our application, we have used an aftermarket 15KΩ@25ºC NTC bead thermistor, with a 5% tolerance.

The thermistor is attached with a clip on a resistive load of 20Ω/25W, which in turn is powered by a variable DC power supply, in order to induce the demanded temperature, thus changing the thermistor's resistance accordingly (Fig. 1.). A K-thermocouple is also attached to the heater to make manual comparative measurements and calibrations with a multimeter.

The thermistor is connected in series with an ≈15KΩ resistor and the resulted voltage divider is further connected to the analog input of an open source acquisition board.

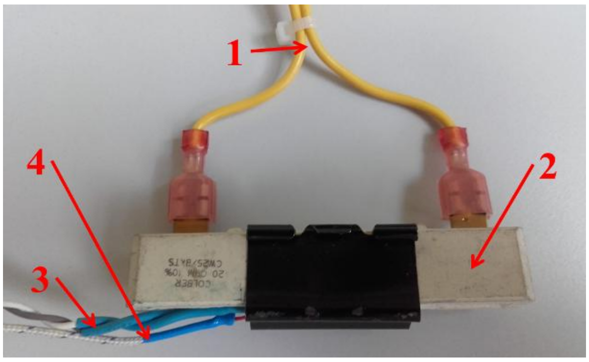

*Fig. 1 Temperature testing platform components: **1**-adjustable DC power supply leads; **2**-heating resistor; **3**-NTC thermistor; **4**-multimeter K-thermocouple.*

The open source acquisition board we used in our experimentation, is comprised of an Arduino Uno and a SD/RTC CSV logger shield, for data harvesting and timestamp, regarding the measured resistance and temperature of the thermistor (Fig. 2.).

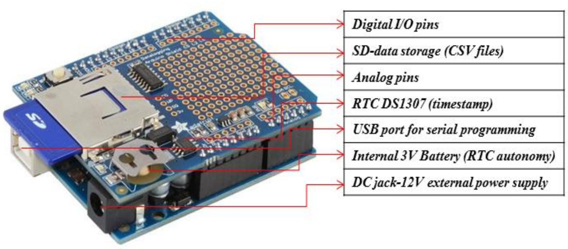

Fig. 2 Arduino Uno based acquisition board with stacked on CSV logger shield used for the thermistor testing platform.

The board uses the 2^{10} ADC (analog-to-digital-converter) to convert the input voltage from the thermistor voltage divider, on the analog pin (A0), into discrete values for resistance (*Ω*) and temperature (*°C*) (Fig. 3.).

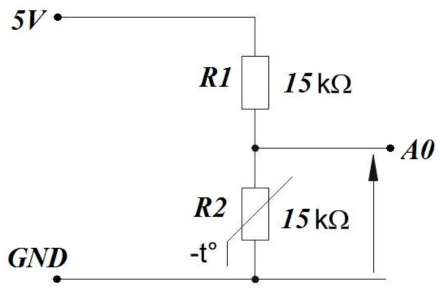

Fig. 3 Voltage divider adaptation for thermistor measurement.

Furthermore, the data is logged onto the SD card for later processing and the sampling rate is done at 500ms, enough time for the board to capture steps of 0.2°C, when the temperature is changed incrementally.

The algorithm was build based on previous manual multimeter tests (measurements of *RT*) with the thermistor and the K-thermocouple, for calculation of the Steinhart A, B and C coefficients, in order to introduce them, as predefined float values into the algorithm (Fig. 4.).

The algorithm also extracts the resistance value of the thermistor (R2), based on calculations in relation to the predefined value of the series resistor (R1) of 15.2KΩ.

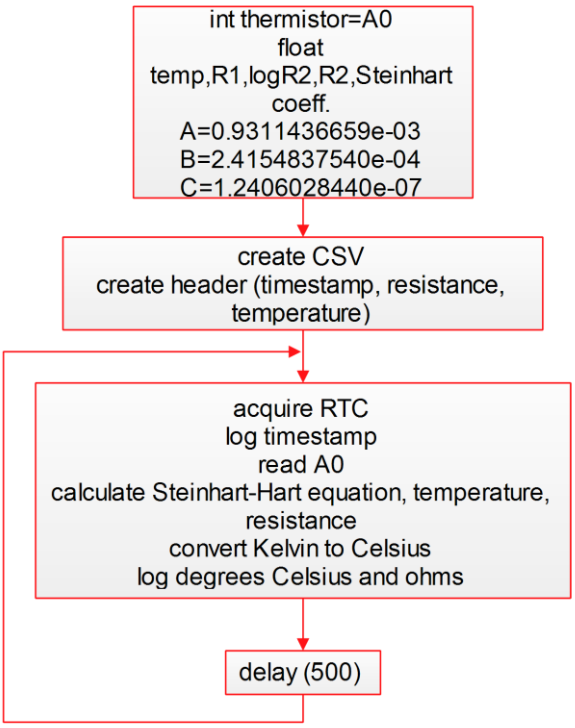

Fig. 4 Flowchart of the algorithm implemented into the open source platform.

Three stages of experimentation were conducted in order to make proper final RT measurements with the open-source platform.

The ***first stage*** required manual data acquisition with the multimeter - of resistance (R), by using the thermistor, and of temperature (T), by using the K-thermocouple. Based on the acquired RT results, the A, B and C Steinhart coefficients were manually calculated by using three points of reference (*R@25ºC*, *R@45ºC* and *R@65ºC*).

The ***second stage*** required the insertion of the three Steinhart coffeicients calculated values, into the algorithm formula, as predefined float values for the new RT measurements.

The ***third stage*** required a new set of RT data acquisition, this time automatically, with the open-source platform, by using only the thermistor. Thus our system acted both as a Ohm meter and thermometer. Based on the RT measurements, a comparative graph was manually built.

Basically, by using this method, we could calibrate the open-source platform by the multimeter, if we regarded the multimeter as an ideal reference point for precise measured RT values.

3. EXPERIMENTAL LABORATORY RESULTS

Conducting the laboratory experiments, with incremental change of temperature and thus resistance of the thermistor, a table was generated, with the comparative measurements (*RT*) of the multimeter (manual) and the open-source platform (CSV file) (Table 1.1.).

Table 1.1 Multimeter vs open source platform, RT measurements.

Temperature (*T*)	**Multimeter (*R*)**	**Open source Platform (*R*)**
25ºC	14.46KΩ	14.43KΩ
30 ºC	11.8KΩ	11.9KΩ
35 ºC	9.74KΩ	9.81KΩ
40 ºC	8.07KΩ	8.15KΩ
45 ºC	6.68KΩ	6.77KΩ
50 ºC	5.57KΩ	5.67KΩ
55 ºC	4.65KΩ	4.76KΩ
60 ºC	3.94KΩ	4.02KΩ
65 ºC	3.34KΩ	3.4KΩ

The resulted RT curve [4], for both measurements was very similar, achieving a very low error tolerance, taking the multimeter data as a reference point (Fig. 5.). The measurement sets consisted of nine samples with a resolution of 5ºC, starting at 25 ºC to 65 ºC. The gross resistance varied from 14kΩ to 3kΩ, according to the temperature change.

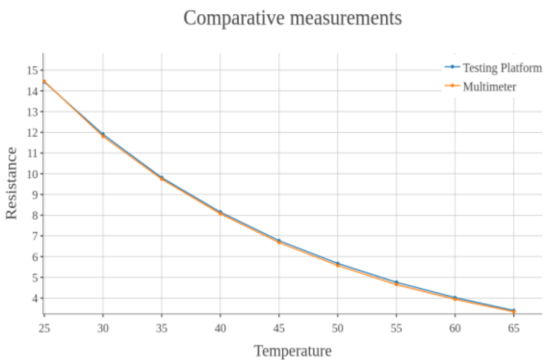

Fig. 5 Plotted RT curve comparison of the two measurement sets from the multimeter data set and the open-source platform data set.

The full experimental rig with components description is presented in Fig. 6. In this stage, the multimeter and the K-thermocouple are used only for temperature display, while heating up the power resistor, while the standalone open-source platform takes RT measurements on the SD-card.

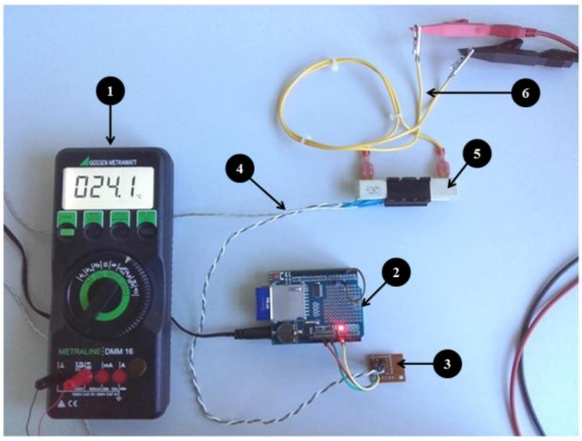

*Fig. 6 Experimental rig at work taking first calibration measurements: **1**-multimeter; **2**-open*

*source CSV datalogger; **3**-voltage divider; **4**-NTC thermistor and K-thermocouple; **5**-heating resistor with clamp; **6**-DC adjustable power supply leads.*

The Table 1.2 reveals the calculated Steinhart-Hart coefficients for each set of data, after the acquisition.

Table 1.2 Multimeter vs open source platform, Steinhart coefficients A, B and C.

Steinhart-Hart coefficients	Multimeter	Open source platform
A(e^{-3})	0.9311436659	1.037342665
B(e^{-4})	2.4154837540	2.211542606
C(e^{-7})	1.2406028440	2.261644602

The Steinhart-Hart equation used for calculation of the coefficients is described in relation (1) [5]:

$$\frac{1}{T} = A + B\ln(R) + C[\ln(R)]^3 \qquad (1)$$

Judging by the final results analysis, we can confirm that the experiment was successful regarding the precision of measurements, stability and effectiveness. Thus, it can very well be used as aid for further testing purposes or research.

4. CONCLUSIONS

Aftermarket thermistors can sometimes bear hidden problems from one manufacturer to another. Although some have the tolerance percentage marked as a color code, some doesn't even have these codes written at all, and even more, can often misslead the consumers as they can have totally different tolerance values (most of them), from the ones written or stated in the datasheets.

In conclusion, the empirical research is needed in order to work properly with unknown manufacturer electronic products.

Thermistors are widely used in central heating systems, cars, medical care, weather stations, computer components, power supplies, washing machines, 3D printers, fire detectors and most electronic boards that require overvoltage or overcurrent protection, thus they are indispensable from our daily use electronic devices.

The acquired data from these electronic components can help us to better improve the processing algorithms and calculation subroutines, resulting in higher precision and quality of the electronic projects that we will further build for research purposes.

The open source platform used in our experimentation can be adapted to achieve different kinds of measurements for different electronic components such as: PTC thermistors, fixed resistors, TEC/TEG modules, thermocouples, batteries or any analog/digital sensors.

In this paperwork we have demonstrated a *proof of concept*, by using a low cost and highly available on the market programmable electronic platform, for the representation of the NTC thermistor RT electrical characteristics [6].

By using the Steinhart-Hart equation and by manually calculating the A, B and C coefficients after each data set, we could achieve, by repeated acquisitions and corrections, an almost precise calibrated algorithm for an open-source platform by a laboratory multimeter, regarding RT measurements. The advantage of our system is that it can automatically take RT measurements with the precision of a multimeter, and store the numerical data as CSV file for the later graphic representation of the curve.

5. REFERENCES

[1].www.thermistor.com/sites/default/files/white-papers/Beta-vs-Steinhart-Hart-Equations.pdf

[2].Macklen E.D., "*NTC Thermistor Materials*", Ed. RJ BROOK, "*Concise Encyclopedia of Advanced Ceramic Materials"*, Pergamon, 1991, Pages 328-331, ISBN 9780080347202.

[3] E., "*Measuring temperature with NTC-The Steinhart-Hart Formula*", https://arduinodiy.wordpress.com/2015/11/10/measuring-temperature-with-ntc-the-steinhart-hart-formula/, November 10, 2015.

[4].http://www.vishay.com/docs/33002/ntcvtemp.pdf

[5]. John S. Steinhart, Stanley R. Hart, Calibration curves for thermistors, Deep-Sea Research and Oceanographic Abstracts, Volume 15, Issue 4, August 1968, Pages 497-503, ISSN 0011-7471, doi:10.1016/0011-7471(68)90057-0.

[6].http://www.madur.com/pdf/article/en/Thermistors_EN.pdf