TRU-SSS-EEEA-05

INVESTIGATION OF THE CHARACTERISTICS OF TEMPERATURE RELAY[4]

Denis Sami, Bachelor Student
Department of Electronics,
Univesity of Ruse "Angel Kanchev"
Tel.: +359 89 990 3304
E-mail: denis.sami1997@gmail.com

Assist. Prof. Seher Kadirova, PhD
Department of Electronics, Ruse,
Univesity of Ruse "Angel Kanchev"
Phone: +359 82-888-516
E-mail: skadirova@uni-ruse.bg

Assoc. prof. Aneliya Manukova-Marinova, PhD
Department of Electronics, Ruse,
Univesity of Ruse "Angel Kanchev"
Phone: +359 82-888-366
E-mail: amanukova@uni-ruse.bg

Abstract: *Temperature measurement in today's industrial environment encompasses a wide variety of needs and applications. To meet this wide array of needs the process controls industry has developed a large number of sensors and devices to handle this demand. Temperature is a very critical and widely measured variable for most mechanical engineers. Many processes must have either a monitored or controlled temperature. In this paper it has been used a practical solution of the temperature relay module with high accuracy. For achieving this aim practical measurement and program analysis have been made. Also mathematical equation is used in term of proof the accuracy.*

Keywords: *Relay, Temperature, Accuracy, Standart Deviation.*

INTRODUCTION

Today relays is a critical part of automation systems. To achieve a complex logic and control of such a system relays need to be used. These days control modules taking an important part of our lives. It starts from furnitures ON/OFF time controlled buttons to automated self controlled cars. One of the important point in using an electronic module in life is to be a simple and accurate. In most of situation both of requirements is hard to achieve.

The analog electronic model thermal relay is simple, cheap and precise which can be installed easily, and is a protector tailored for small and medium-sized motors (Gong Shu-qiu, Gao You-hua, & Li Zhong-bo, 2002).

The traditional bimetal relay can not protect the electromotor because of the shortcomings such as thermal fatigue which can not overcome (Cui L., Gong S., Li J., & He B., 2009).. In this paper it has been used a practical solution of the temperature relay module with high accuracy. For achieving this aim practical measurement and program analysis have been made. Also mathematical equation is used in term of proof the accuracy

Schematic shown above (Fig. 1) is a simple temperature relay. It is separated in two parts. First part is a switching module (Relay), power and filtering and LED indicator for a modul activation. The second part includes control system.

[4] Докладът е представен на студентската научна сесия на 09.05.2019 г. секция EEA с оригинално заглавие на български език ИЗСЛЕДВАНЕ НА ХАРАКТЕРИСТИКИТЕ НА РЕЛЕ ЗА ТЕМПЕРАТУРА

EXPLANATION OF TEMPERATURE RELAY SCHEMATIC

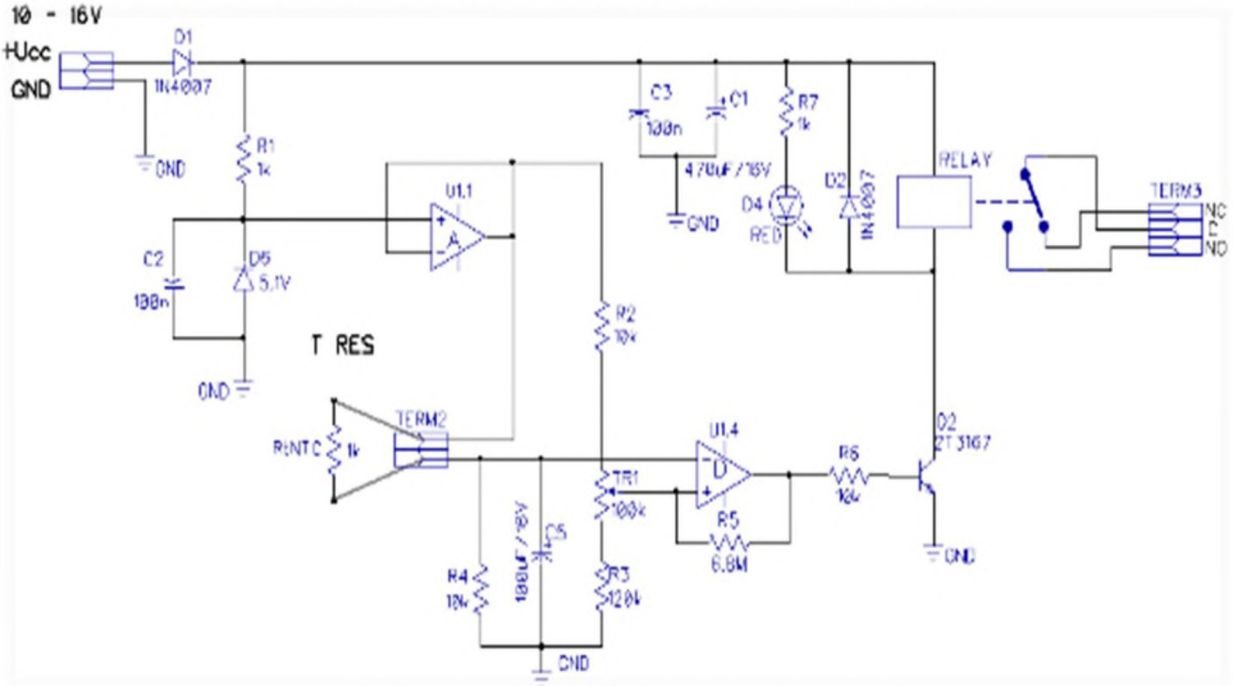

Fig. 1 Schematic of temperature relay

The first part of actuator (switching module) is been realize with a simple relay which is based on a current induced in inductor which is inside. So it is straightforward to activate this module voltage path need to be ensure. For a power supple flitering just a capacitors are being used. An additional component to ensure protection, from user mistake, such a shotky diode D1 can be usefull but is not mendatory. To achieve maximum simplicity just a capacitor to reduce ripple will be enough. The led indicator is developed by LED and current limited resistor. The rectifier diode D2 is used to protect the BJT from break down. When the scheme is stoped after working condition, the relay has induced current inself which need to be desipated. To accomplish this task it needs D2 to create a shorted path and desipate the charge with intrinsic resistor.

The second part of a control system have been realize with an analog descrete parts. This schematic gives opportunity to control the temperature relay simply with turning the knob of a variably potentiometer. The princip of work is based on a switching comparator. As it shown in schematic series resistors R2, TR1 and R3 creating a resistive devider which sets switching level of comparator. With this type of schematic we can configure the temperature control system. The R1 is a limited current resistor which is charging the capacitor C2. The C2 will be charged until it reaches 5.1V which is limited by zener diode. The 5.1V is being buffered from Ul1 follower in two nodes. The output value is 75-80% of an input value. First node includes thermistor which is NTC (negative temperature coefficient), R4 and C5. This thermistor limiting current through capacitor. R4 is for discharging the capacitor. The charging of capacitor is voltage dependent:

$$I = C * \frac{dv}{dt}$$

The resistors Rt and R4 are connected in parallel which Req limiting current through C5:

$$Req = \frac{Rt * R4}{Rt + R4}$$

Also this both resistor transforming voltage to current which is being charge in C5:

$$I = \frac{Vin}{Req}$$

So after a voltage has been charged enough and it is applied to comparator it switches. The R5

resistor is creating switching levels. This helps the circuit to be robust for noise, which makes it realy accurate. R5 resistor works as voltage to current convert which current activate Q2 and creating fully path of relay.

Layout and practical problems and solutions:

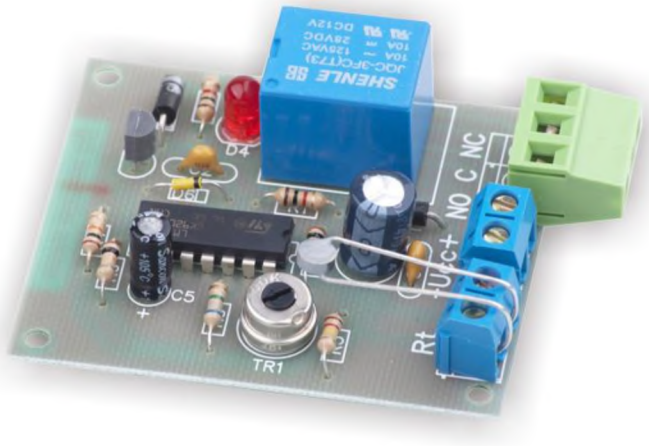

Fig. 2 Real module

The only thing that should be consider is the size of the module (Fig. 2). It need to be small as much as possible to avoid the self temperature problems. If the ambient temperature increase than the transistor and passive component parameters also changes. But if the temperature of all elements changes in same way so we can achieve a thermal stability correction with additional circuit. That's why it is realy important size to be as small as possible.

Results:

The measurement was being made in university labrotory. The variable resistor has been changing in an equivalent small steps and temperature has been measured. Same test methodology has been made in a computer circuit design program. After that results is being compared and it has been made some editional mathematical calculation for standart deviation and was create a Gaussian distribution for a results representation.

Table 1. Circuit design program analyze for temperature accuracy

№	V [V]	Rp [kΩ]	T [°C]
1	2.66	0	5
2	2.88	10	6
3	3.1	20	8
4	3.33	30	12
5	3.55	40	16
6	3.77	50	20
7	3.99	60	24
8	4.21	70	28
9	4.43	80	32
10	4.65	90	36
11	4.88	100	40

Table 2. Real measurement for temperature accuracy

№	V [V]	Rp [kΩ]	T [°C]

1	2.56	0	5
2	2.88	10	6
3	2.98	20	8
4	3.35	30	12
5	3.45	40	16
6	3.97	50	20
7	4	60	24
8	4.19	70	28
9	4.53	80	32
10	4.81	90	36
11	4.91	100	40

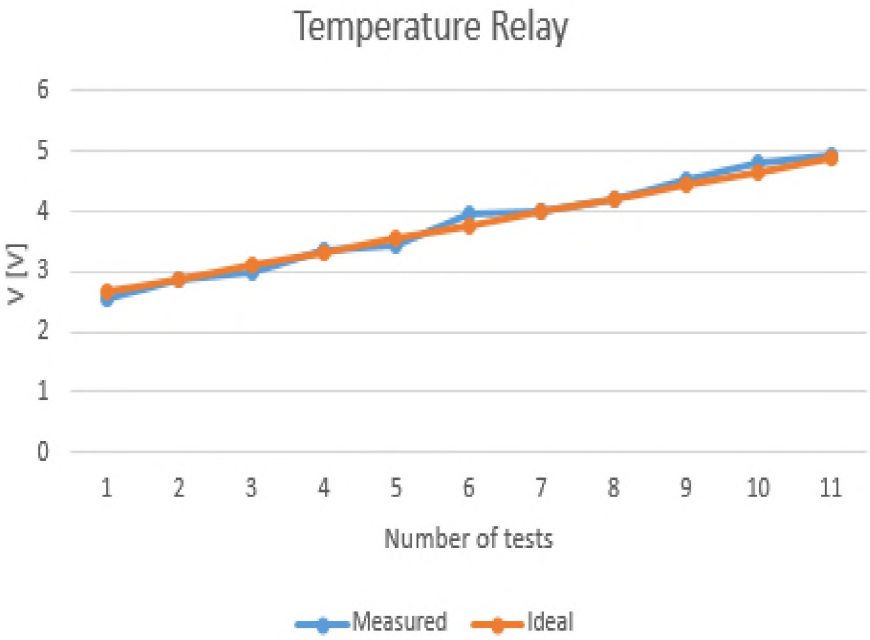

Fig. 3 Graphical representation of deviation between simulation and real practical taken values.

As it seen in the table and in graph we have deviation between simulation and real practical taken values. Also the errors need to be taken in account such as human mistake, thermometer accuracy, module temperature and e.t.c.

First mean value has been calculated:

$$\bar{x} = \frac{\sum x}{n}$$

$\bar{x}$ – Mean value

$\sum x$- Sum of measurement values

n – Number of sum components

After that standard deviation has been calculate:

$$\sigma = \sqrt{\frac{1}{N}\sum_{1}^{N}(xi - \mu)^2}$$

σ – Standard Deviation

N – Number of sum components

x_i – each value of measurement

μ – mean value

Table 3. Measured voltage of switching the BJT and calculated mean value of each

№	1	2	3	4	5	6	7	8	9	10	11
1	2.6	2.85	3	3.4	3.7	4.1	4.2	4.18	4.55	4.85	5
2	2.58	3	2.8	3.45	3.8	3.8	4.1	4.2	4.53	4.8	5.2
3	3	3.2	2.95	3.5	3.3	3.7	4.05	4.22	4.5	4.75	4.8
4	2.6	2.7	3.1	2.8	3.6	4.2	3.95	4.21	4.48	4.8	4.7
5	3	2.8	3	2.9	3.4	3.9	3.97	4.16	4.55	4.73	4.6
6	2.8	2.65	2.99	3.2	3.3	4.2	3.8	4.17	4.54	4.83	5.3
7	2.3	2.9	2.98	3.4	3.2	3.8	3.9	4.19	4.55	4.85	4.6
8	2	2.9	3.01	3.6	3.3	3.9	4	4.2	4.54	4.84	4.74
9	2.12	2.9	2.98	3.6	3.2	4.11	4.1	4.19	4.52	4.8	5.25
10	2.6	2.9	3.01	3.65	3.7	3.99	3.9	4.18	4.54	4.81	4.91
Measured μ	2.56	2.88	2.98	3.35	3.45	3.97	4	4.19	4.53	4.81	4.91
Simulation μ	2.66	2.88	3.1	3.33	3.55	3.77	3.99	4.21	4.43	4.65	4.88

For three value of the table the Gaussian distribution has been calculate:

σ = 0.32

μ = 2.56

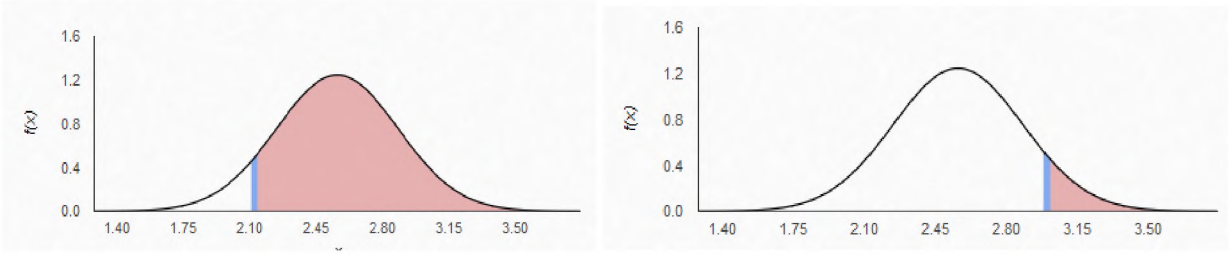

Fig. 4 Graphical results

σ = 0.168

μ = 3.97

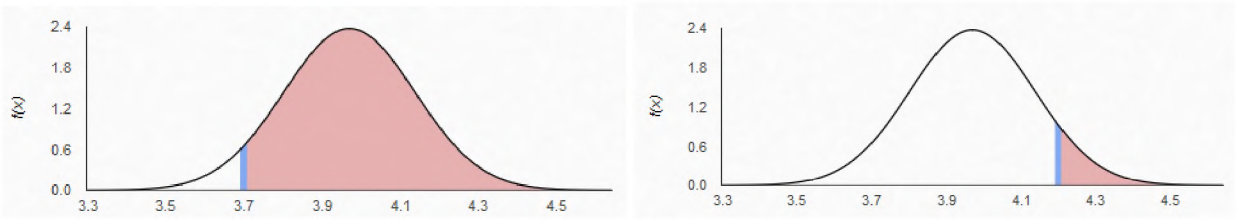

Fig. 5 Graphical results

$\sigma = 0.25$

$\mu = 4.91$

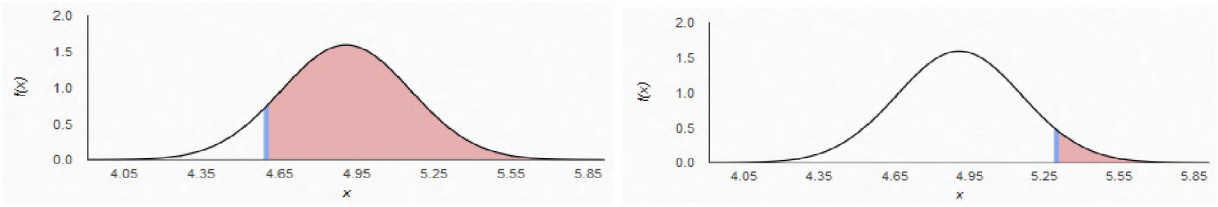

Fig. 6 Graphical results

As seen in the Gaussian distributions the standart deviation is reaching 3 times σ which is 99.7%. This shows that this module will work with high accuracy. Also with temperature, increasing of the ambient the madule is not much affect because of its size and less dependent component except transistors and IC's.

CONCLUSION

In this paper, we have proposed a new, simple, low cost and high accurate relay module. Measurement results demonstrated a high accuracy in a self increasing temperature and noise. The control module can be flexibly customized to get a higher performance in automation system. The simplicity and straightforward design produce a cost-effective, compact solution for artificial control system and complicated logic.

ACKNOWLEDGEMENTS

The article presents results from Project 2019 - FNI - FEEA - 05, with financial support of the National Science Fund of University of Ruse "Modelling and investigation of objects controlled by electronic systems".

REFERENCES

Gong Shu-qiu, Gao You-hua, & Li Zhong-bo, (2002) *Investigation of The Reverse Time Curve for The Electronic Motor Protection Device* [J].Application of electronic technique Vol. 28 , No. 4 pp.42-44

Cui L., Gong S., Li J., & He B., (2009) *Research of the inverse time characteristic curve for the electronic thermal relay*, 9th International Conference on Electronic Measurement & Instruments,