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Multichannel Temperature Monitor on IoT

Jaroonrut Prinyakupt*, Thanakorn Yootho
Faculty of Biomedical Engineering
Rangsit University
Phathumthani, Thailand
*jaroonrut.p@rsu.ac.th

***Abstract*— The objective of this study was design and construction of 4 channels temperature monitor via IoT system by using the compensate error sensor and microcontroller for measure the worker skin temperatures in occupational health field. This prototype composed of three parts: 1) the measurement part consisted of calibrated temperature sensors, 2) the processing part composed of NodeMCU 1.0 microcontroller work on Wi-Fi, and 3) the display part comprised of monochrome 0.96" 128X64 OLED and displayed via IoT platform. The designed prototype give a good accuracy and easy to access.**

***Index Terms*— multichannel, temperature measurement, IoT.**

I. Introduction

Nowadays occupational health task play high role in the industrial for develop life quality of worker's in work place. Temperature measurement is also an importance issue in occupational health field. Working on extreme hot or cold weather are dangerous for example, exposure of the excessively high temperature bring to heat stress while exposure of the excessively low temperature bring to cold stress. The most concern is heat stroke and hypothermia which could be fatal in medical attention. So worker temperature monitoring play an importance role in planning and managing occupational health safety guideline policy. Traditional temperature monitor instrument need high accuracy as such as in medical field but size and price still drawback. Therefore the designed device for support this problem is necessary.

There are many research give attention in remote temperature monitor design with several method to send and receive temperature data. Popa, M. et.al. [1] monitored and regularized indoor temperature by use PIC16F876 microcontroller by transmit and receive data with radio frequency. James, C.A., et al. [2] measured skin temperature with hard wired thermistors, telemetry thermistors and thermal camera during exercise in heat and calculated reliability and validity of each technique in both water bath and during exercise. Furthermore, Ling, T.H.Y. and L.J. Wong [3] monitored body temperature of elder using infrared concept and made a tele-monitoring system with XBee wireless protocol.

Since the one problem of temperature monitoring in worker is the instrument is expensive. Typically skin temperature (T_{Skin})) was measured with thermocouple or thermistor. Sensor with high accuracy, their price is even more expensive. There are digital temperature sensor, Maxim DS18B20, with high precision but accuracy is $\pm$ 0.5°C which higher than scientific acceptance. However the manufacture recommended a mathematical method for improve the accuracy of the sensor [4].

Nowadays, the development of the microcontroller boards is rapid growth. ESP8266 is also a chip that cans wirelessly networkable microcontroller modules. The development Kit based on ESP8266 used in this research is NodeMCU which integrates GPIO, PWM, IIC, 1-Wire and ADC all in one board.

Analysis of T_{Skin} measurements used the derivative calculation mean T_{Skin} using the formula of Ramathan according to James, C.A., et al. [2], thus this research we try to monitor 4 channel temperature by using sensor DS18B20 and apply embedded microcontroller board to send data via Wi-Fi and display on both OLED and thingspeak.com which is an IoT platform.

In this paper, we present a method to detect temperature and calibrate digital temperature sensors and publish data via IoT. We present the details of our proposed method in section II. Section III shows the experiment results obtained from our method. Discussion and conclusion were showed in section IV.

II. Proposed Method

Material and instruments used in this research as describe:

1. NodeMCU V1.0 (ESP 12E module)
2. Mobile phone with Wi-Fi Hotspot
3. 4 x DS18B20
4. Monochrome 0.96 128x64 OLED graphic display SSD1306 with SPI interface
5. Temperature data logger OM-CP-HITEMP150 N02776
6. Refrigerated incubator brand VELP Scientifica model FOC 225I
7. Water bath brand Vision Scientific co. ltd.

The designed hardware was divided into 3 main part: input part, processing part and output part as shown in Fig 1.

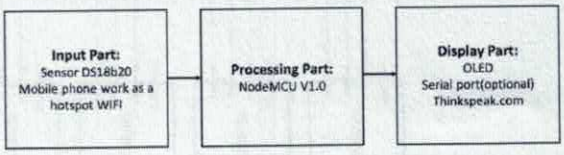

Fig. 1. Block diagram of the proposed method

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A. Input Part

The sensor used in this research is DS18B20 digital temperature sensors with high precision. Since NodeMCU have a limited input port and this sensor is 1-wired type that use only one wire programing by identify address the sensor. The accuracy of this sensor is ± 0.5 °C then it need to compensate error.

1) Circuit of 1-wire sensor

Advantage of 1-wire sensor is only one pin of board were used but need to specify sensor index correctly. The circuit of 4 channel DS18B20 temperature sensors was shown in Fig 2.

2) Sensor calibration step

The skin temperature is around 20-40 °C while the error curve of the sensor [5] was shown in Fig 3. We recorded the sensor's temperature in some temperature points and compared the mean and standard deviation of temperature data with the calibrated temperature data logger N02776. We designed experiment by using the water bath (for temperature setting at 30, 35, 40, 45°C) and the refrigerator incubator (for temperature setting at 15, 20°C). Each temperature setting was recorded for 2 hours. We selected time duration that temperature of the calibrated temperature data logger was stable and compared temperature reading from our sensors by download data from thingspeak.com, at the same duration time. Then, we calculated the error of each temperature's point as recommended by manufacturer [4]. The error equation was shown in equation (1) and the compensated temperature was calculated with equation (2) respectively.

$$error = offset + \alpha\left(T_{TS} - T_{Zero\ Slope}\right)^2 \qquad (1)$$

$$T_{comp} = T_{TS} - error \qquad (2)$$

When T_{TS} is the temperature measured by the temperature sensor, α is a curvature correction coefficient, $T_{Zero\ Slope}$ is the temperature at which the error curve has zero slope and $offset$ is the error at $T_{Zero\ Slope}$.

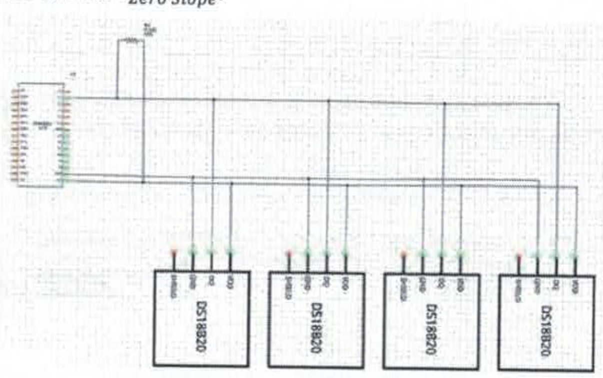

Fig. 2. Circuit of 4 DS18B20 with NodeMCU

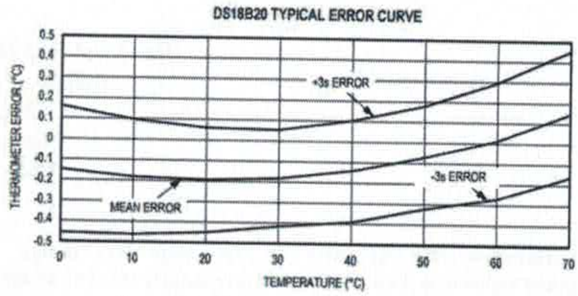

Fig. 3. DS 18B20 typical error curve [5]

B. Processing part

ESP8266 NodeMCU development board was used for connect to Wi-Fi and send temperature data via specific channel in thingspeak.com, IoT application, the flow chart of program as shown in Fig 4.

C. Display Part

1) OLED SPI connection

OLED was connected to NodeMCU board with SPI interface.

2) Temperature monitoring via IoT step

We use thingspeak.com, an open data platform, for communicate and export data in CSV format. Channel setting page given the information about channel id and API key for programing into NodeMCU as shown in Fig 5. Fig 6 (b) was a 4 channel temperature data display.

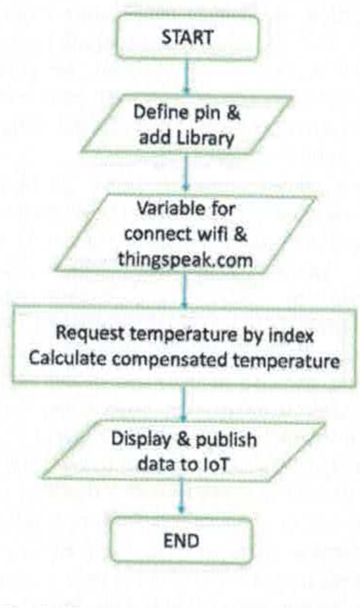

Fig. 4. Flow chart of the processing part.

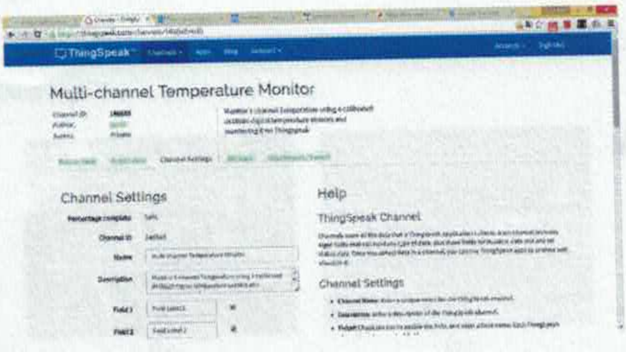

Fig. 5. Channel setting in Thingspeak.com

Our work flow was divided into 3 stages as data collection, data analyzation, and reprogram.

1) Data collection stage:

a) Set temperature of water bath at 30, 35, 40, 45°C. Each temperature setting was recorded for 2 hours by using our designed prototype and the temperature data logger. Do the same with the refrigerator incubator at 15, 25°C.

b) Record the calibrated temperature data every 15 second.

c) Select only the stable temperature data for the calibrated temperature data logger. Select the recorded data of each sensor at the same time duration. The time durations were chosen from the data set with the smallest SD that mean the data set clustered closely to the average data.

2) Data analyzation stage:

a) Calculate mean and standard deviation (SD) of the calibrated temperature data logger and each sensor.

b) Compute the error of each temperature point for each sensor.

c) Find the quadratic equation's parameter of error data.

3) Reprogram stage:

a) Reprogram by using the observed parameter.

Record and compare our data, which access from each sensor, with the calibrated temperature data logger as same as the data collection stage.

III. Results and Discussion

The designed device was able to measure the 4 temperature channels, display through the OLED and connect Wi-Fi signal to publish the data to thingspeak.com as shown in Fig 6 (a) and (b). We measured temperature cover 20-40 °C rang using water bath and refrigerator incubator as shown in Fig 6 (c) and (d).

The results of the temperature data for each sensor before and after compensated temperature were shown in TABLE I and II respectively.

Since the interested temperature range is between 20 - 40 °C, the error equations were written in quadratic form as in equation (3) by using the interested temperature range. The parameters of each sensor were shown in TABLE III.

Errors at each temperature sensor before and after temperature compensation were compared as shown in Fig 7.

TABLE I. The result of temperature reading for each sensor before temperature compensation.

Temp data logger		Sensor# 1			Sensor# 2			Sensor# 3			Sensor# 4		
Mean (°C)	SD	Mean (°C)	SD	Error (°C)	Mean (°C)	SD	Error (°C)	Mean (°C)	SD	Error (°C)	Mean (°C)	SD	Error (°C)
12.844	0.045	13.236	0.056	-0.391	13.308	0.046	-0.464	13.506	0.05	-0.661	13.314	0.043	-0.47
22.673	0.057	22.873	0.073	-0.2	23.147	0.099	-0.473	23.151	0.074	-0.478	22.984	0.047	-0.311
30.022	0.027	30.072	0.034	-0.05	30.17	0.038	-0.148	30.363	0.04	-0.341	30.177	0.049	-0.155
32.702	0.033	32.746	0.04	-0.044	32.813	0.025	-0.111	33.02	0.042	-0.317	32.836	0.049	-0.134
35.285	0.026	35.29	0.031	-0.005	35.347	0.038	-0.062	35.573	0.049	-0.288	35.383	0.036	-0.098
42.489	0.061	42.367	0.078	0.122	42.468	0.085	0.021	42.601	0.073	-0.112	42.452	0.066	0.037

TABLE II. The result of temperature reading for each sensor after temperature compensation.

Temp data logger		Sensor# 1			Sensor# 2			Sensor# 3			Sensor# 4		
Mean (°C)	SD	Mean (°C)	SD	Error (°C)	Mean (°C)	SD	Error (°C)	Mean (°C)	SD	Error (°C)	Mean (°C)	SD	Error (°C)
12.892	0.051	13.020	0.032	-0.128	12.954	0.028	-0.061	13.010	0.043	-0.118	13.009	0.033	-0.116
22.757	0.036	22.952	0.046	-0.195	22.853	0.034	-0.097	22.893	0.043	-0.137	22.938	0.041	-0.181
29.136	0.050	29.127	0.040	0.009	29.038	0.027	0.098	29.106	0.018	0.031	29.056	0.027	0.080
32.807	0.040	32.815	0.048	-0.009	32.793	0.049	0.014	32.815	0.046	-0.008	32.796	0.041	0.011
38.254	0.040	38.248	0.064	0.006	38.303	0.083	-0.049	38.318	0.094	-0.064	38.198	0.039	-0.013
42.503	0.034	42.427	0.046	0.076	42.527	0.073	-0.024	42.507	0.082	-0.004	42.398	0.039	0.003

(a) (b) (c) (d)

Fig. 6. (a) The prototype, (b) the thingspeak.com data, (c) the experiment was tested with the water bath, (d) the experiment was test with the refrigerator incubator.

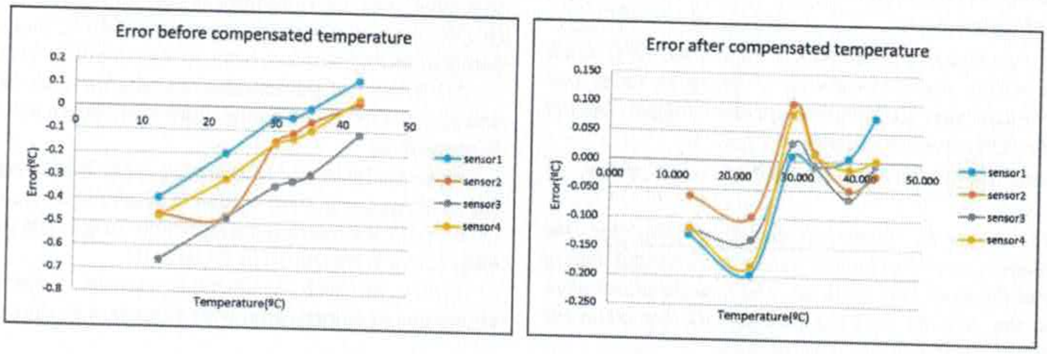

Fig. 7. Error at each temperature setting before and after temperature compensation

$$error = a\,T_{TS}^{\;2} + bT_{TS} + c \quad (3)$$

TABLE III. THE PARAMETER OF EACH SENSOR FOR TEMPERATURE COMPENSATION.

Sensor No.	a	b	c
1	-0.00011155	0.023168	-0.6685
2	0.000133023	0.011832	-0.67973
3	5.01873E-05	0.01515	-0.85843
4	-1.1585E-05	0.017708	-0.69692

IV. CONCLUSION

The purpose of this paper is design the device that able to measure the 4 channels temperatures, displayed through the OLED and connect Wi-Fi Hotspot for publish data to thingspeak.com, which is the IoT platform, then we collect data by download our published data from thingspeak.com and compare data at the same time duration with the data logger.

Furthermore, we also design the experiment to find variables for compensated error. Even though, the procedure of finding the parameter for compensated temperature of each sensor was time consuming, but all of those sensors gave better solution than before compensation procedure.

ACKNOWLEDGMENT

We are thankful to Faculty of Biomedical Engineering, Rangsit University for supporting the temperature data logger. We are also grateful to our colleagues from Chemistry and Biochemistry Department, Faculty of science, Rangsit University who provided the equipment that greatly assisted the research.

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