Jurnal Teknokes
International: Rapid Review: Open Access Journal Vol. 16, No. 1, March 2023, pp. 14-20 e-ISSN 2407-8964; p-ISSN 1907-7904

RESEARCH ARTICLE OPEN ACCESS

Manuscript received January 18, 2023; revised March 10, 2023; accepted March 12, 2023; date of publication March 25, 2023
Digital Object Identifier (**DOI**): https://doi.org/10.35882/teknokes.v16i1.506

How to cite: Dianti Mayasari, Syaifuddin, Dyah Titisari, "Analysis of Temperature Distribution Using 7 DS18b20 Sensors Equipped with Data Storage and IoT Monitoring ", Jurnal Teknokes, vol. 16, no. 1, pp. 14–20, March. 2023.

Temperature Distribution Monitoring on Blood Bank Chamber Using Android Application on Mobile Phone

Dianti Mayasari[1] , Syaifuddin[1], Dyah Titisari[1], and Triwiyanto[1]

[1]Department of Medical Electronics Technology, Poltekkes Kemenkes Surabaya, INDONESIA
[#]Corresponding author: Syaifudin (email: syaifudin@poltekkesdepkes-sby.ac.id)

ABSTRACT Blood cold chain is a mandatory requirement of blood donation procedures to protect blood from bacterial contamination and to extend the shelf life of blood. Blood bank as a storage medium for blood bags requires a temperature between 2°C-6°C on average. However, in general, blood banks only have 1 cold temperature distribution point, which is feared that the spread of cold temperatures in the compartment will be different at each point. For this reason, the researcher intended to design a blood bank temperature distribution monitoring device consisting of 7 measurement points. In this case, temperature sensor readings at each point are displayed wirelessly to smartphone devices using the Blynk platform and are also on a 3.5-inch TFT screen. The measurement data were then stored on the SD card memory so that the level of temperature fluctuations in the blood bank compartment can be analyzed during use. The module was also equipped with an alarm warning on the module and the Blynk application if the temperature is out of the normal temperature range (2°C-6°C). Before being used for measuring temperature distribution, the device made was compared with the standard Fluke DPM4 tester, in which the highest error obtained was 2.08% at T1, 1.58% at T2, -2.73% at T3, 1,61% at T4, -1.07% at T5, -0.06% at T6, and -2.32% at T7. After being compared with standard equipment, the device was used to measure the temperature spread in the Kirsch brand blood bank and the average temperature obtained was 3.56°C at T1, 3.58°C at T2, 3.73°C at T3, 3.57°C at T4, 3.67°C at T5, 3.63°C at T6, and 3.72°C at T7. Based on the analysis results, the blood bank monitoring device can be used to measure the temperature spread in the blood bank compartment at 7 measurement points. Furthermore, temperature readings can be monitored wirelessly and remotely. It is hoped that this research can further help laboratory personnel at the Blood Transfusion Unit to monitor and evaluate the level of temperature spread in the blood bank compartment and prevent early damage to blood components.

INDEX TERMS Blood Bank, Temperature, Cold chain, Blynk.

I. INTRODUCTION

Stored blood is blood that has been stored for more than six days after blood collection. The temperature used for storage of blood components ranges from 2°C to 6°C and the temperature must always be monitored [1][2]. Blood stored at temperatures that are not recommended will result in the decrease of blood's ability in delivering oxygen. The storage of blood at a temperature of 2-6°C is done to reduce the growth of bacterial contamination in stored blood. Meanwhile, storage at temperatures above 6°C causes the growth of bacteria very quickly so that blood transfusions can be fatal for the recipient of the blood [3]. The temperature limit of 2°C is also very important because red blood cells are very sensitive to clotting, where if the red blood cells freeze, the blood cell walls will burst and the hemoglobin will come out (hemolysis) [4][5]. Therefore, blood banks need to ensure the quality of blood so that there is no risk of damage during storage. According to the guidelines of the World Health Organization (WHO), the temperature in the storage area of a hospital blood bank should be between 2°C to 6°C with a validity of ± 1°C in order to maintain the blood quality [6]. Thus, the blood bag storage container must not only be equipped with a cooling system, but also must have a reliable temperature control system. Looking at the above explanation, it is clear that there is a well-defined need for a container that can store blood bags within a certain temperature range to maintain the blood quality. The temperature of the blood storage area should be periodically calibrated. Such procedure is carried out to calibrate and check the temperature of the enclosure at atmospheric pressure under no-load conditions, in a steady state and regardless of size [7]. Blood that shows an abnormal color or appearance should not be removed for transfusion. Blood vessels should be stored in the original blood container or other container attached to it in a closed system where blood transfer can be carried out without breaking the airtight seal. Blood has an expiration date, where its last day is considered useful for transfusion purposes [8]. The lifespan of PRC (Packed Red Cells) can be extended by keeping the temperature between 2°C-6°C [9]. Storage at temperatures above 6°C causes very fast bacterial growth so that blood transfusions can be fatal for the sufferers who receive them. The 2°C storage limit is also very important because red blood cells are very sensitive to freezing [10]. The blood cold chain is a systematic process for the safe storage and transport of blood starting from the blood collection from the donor to administration to the patient requiring transfusion. Cold chain refers to the blood as a biological substance that must be kept cold to reduce the bacterial contamination and prolong the shelf life of blood. All collected blood was cooled to 4°C and stored at that temperature until transfusion [11]. This is intended to maintain product quality. In the blood storage area in the Hospital Blood Transfusion Unit, hereinafter referred to as UTDRS, temperature is very necessary because it will affect the quality of stored blood products [12]. The current problem is that only a few officers at UTDRS know how the condition of the product storage area is. Several studies have been conducted to find out how the performance conditions in cold chain storage. One of them is the study conducted by C. Vancea in 2011 who conducted monitoring and data recording using wireless with SD Card storage media, but this study has a communication range that is not too far away [13].

In addition, K. Chen in 2011 also conducted a research entitled Applying back propagation network to cold chain temperature monitoring which discusses temperature monitoring in the cold chain. This monitoring was carried out by radio frequency and also recording the measurement results on each cold storage truck. However, this study did not write the temperature distribution in each cold storage [14]. Furthermore, W. Liao conducted a research entitled Sensor Integrated Antenna Design for Applications in Cold Chain Logistic Services in 2015 discussing the distribution in cold boxes using temperature sensors monitored on smartphones. The communication used Bluetooth media so that the data transmission range cannot be too far. In addition, the cold box studied also did not specify the items to be stored in the storage area [15]. In 2016, J. Bellman-Flores with his research entitled Analysis of the flow and temperature distribution inside the compartment of a small refrigerator analyzed the temperature distribution in a conventional refrigerator using a thermal camera. However, the study did not show the setting temperature. In addition, the refrigerator used was a conventional refrigerator which is not intended for medical activities [16]. V. Valcon also wrote his research in analyzing vaccine storage using a temperature data recorder, but this method had no indication of what happened after the data was read [17]. In 2021, Farisy Aziz conducted research on the analysis of temperature distribution in blood banks through storage of measurement results with IOT monitoring in the blood donation unit of PMI Surabaya City. In this study, 3 DS18B20 sensors were placed at 3 different points which were used as input from the device [18].

Based on the research references that have been carried out previously, the author will make an analysis of the temperature distribution according to the Temperature Enclosure Calibration Guidelines at 7 different points in cold storage of blood products. The author's purpose in conducting this research is to let the management knows the real time of the even distribution of temperature and the existence of a warning system in the unit if the temperature exceeds the range of 2°C – 6°C in the blood bank refrigerator for storing blood products at UTDRS [19]. In addition, this activity is also in line with government regulations which if possible there is a temperature recorder in every cold storage of blood products. the regulation referred to as the Regulation of the Minister of Health No. 91 concerning Standards for Blood Transfusion Services [4]. Therefore, through the current research activity, the authors expected to be able to provide a solution for UTDRS who do not have a cold storage monitoring device and can also assist in filling CAPA (Corrective Action Preventive Action) for management if blood products in storage are not in accordance with predetermined blood product specifications.

II. MATERIALS AND METHODS

This research was conducted through an experimental research. The author proposed a temperature distribution monitoring device with SD card storage to measure the temperature condition of the blood bank compartment. This study used DS18B20 as a temperature sensor T1-T7, in which DS18B20 is single bus digital temperature sensor from American Dallas Company which can measure -55℃ to +125℃ with ±0.5℃ sensitivity [20]. As a microcontroller as well as sending data to blynk, ESP32 was used. To store blood bank compartment temperature measurement data, researchers used a micro SD which can store txt files. More detailed methods are described in the section below:

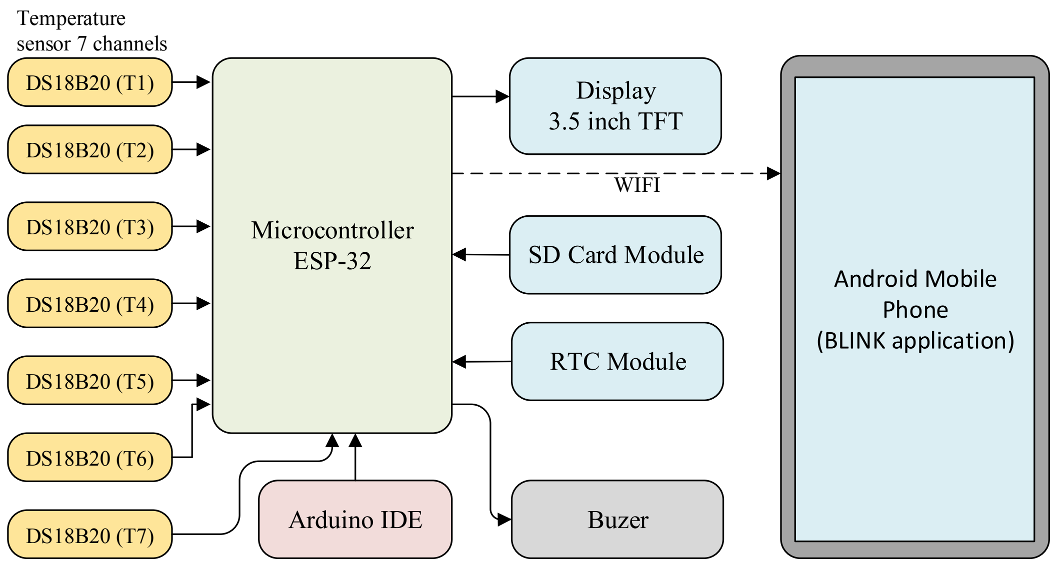

FIGURE 1. block diagram of the entire system of the blood bank temperature distribution monitoring device.

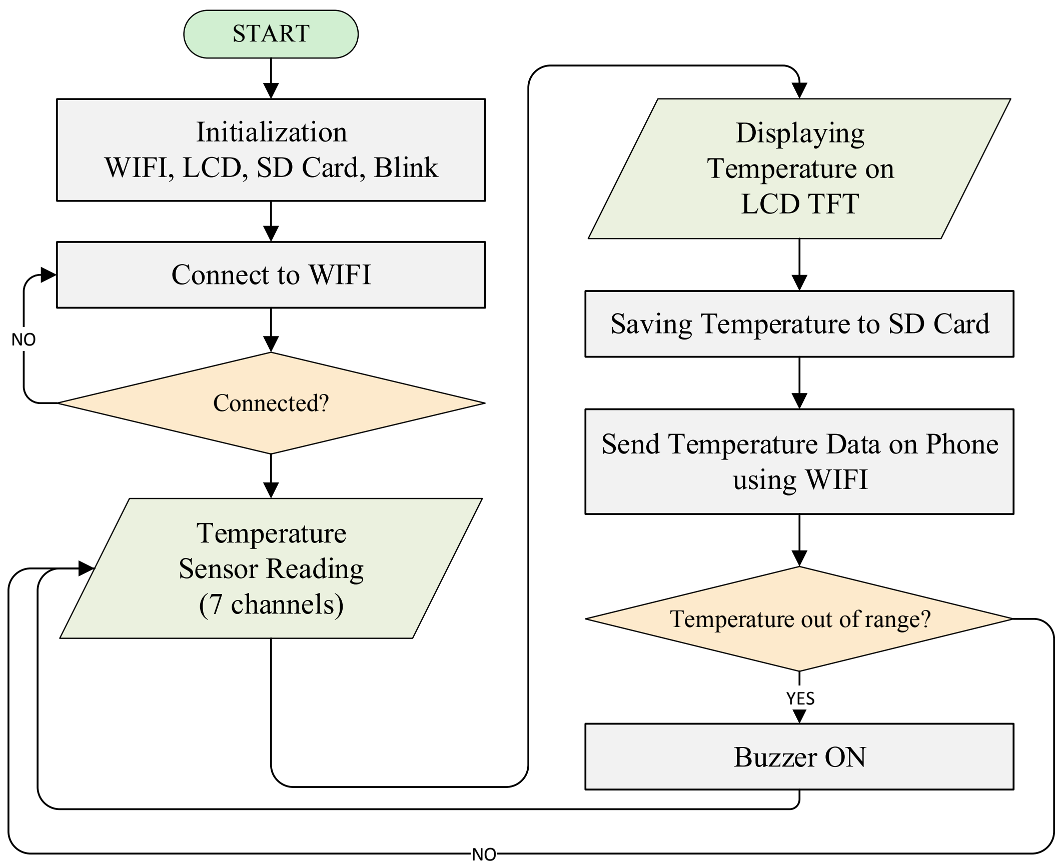

FIGURE 2. Flowchart of the entire temperature parameter measurement.

A. DATA COLLECTION

During the measurement, the sensors were inserted into the blood bank and placed according to FIGURE 1. In this case, the temperature of the blood bank was set at 4°C. After the temperature was stable, the temperature distribution monitoring device was turned on and the measurements were carried out for 60 minutes. The measurement value was then sent to blynk and monitored via mobile phone. Internet of Things (IoT) is a structure in which objects and people were provided with exclusive identity and the ability to relocate data over a network without requiring two-way handshaking between human-to-human i.e. source to destination or human-to-computer interaction [21]. In addition, the number of devices availing internet service is increasing everyday and put a powerful source of information at our finger tips [22]. Meanwhile, in the case of data analysis, it is important to find a storage device to store the large data files used to store temperature sensor reading data [23]. Data logger has been used widely not only in electronic worlds but in all systems which relates to technology. It used for collecting several of data not only for electrical parameters also for meteorological parameters. Apart from being a device whose main job is to store data; it also has the ability of monitoring a system very well i.e. it can record all data required by user and inform user when necessary such as in a faulty situation or any error occurred to the system [24].

FIGURE 3. Location of measurement points T1, T2, T3, T4, T5, T6 dan T7 using the Blood bank.

FIGURE 3 shows the placement of the 7 ds18b20 sensors used to measure the temperature distribution in the blood bank compartment. First, researchers must place 7 sensors according to predetermined points. The measurements were carried out for 60 minutes. After that, the measurement data stored on the sd card were read in excel to find out the graph of the temperature readings and the average from each point.

Furthermore, FIGURE 1 shows a block diagram of the design of the temperature distribution monitoring device used to measure the temperature of T1, T2, T3, T4, T5, T6 and T7 on a blood bank using DS18B20 sensor. It has a unique way of single wire interface. It needs only a mouth line to connect microprocessors and to realize two's two-way communication [25]. The sensor reading results are displayed on the TFT screen and sent to the blynk application. Measurement data can be saved on SD card in device mode. In this case, the researchers used ESP32 as a microcontroller equipped with Wi-Fi 823.11 to connect to the BLYNK application. The benefits of using ESP32 are its simple configuration and good community support [26]. FIGURE 2 shows flow chart of the system. The flow chart on the left shows the design of the microcontroller software and the flow chart on the right shows the design for the blynk application software. After the Arduino initializes, the program will read the sensor readings and display them on the TFT screen. If there is an internet connection, the program will send sensor reading data to the blynk application. On the blynk application side, the data sent by ESP32 was stored on the SD card. Such as the research conducted by Hasanat et al [27], this device also sends a notification if there is one point that is outside the normal temperature range to the Blynk application.

B. DATA ANALYSIS

Measurement of each parameter (temperature, humidity and noise) was repeated 50 times every 30 seconds at each setting of 32°C and 36°C incubator temperature. Furthermore, in the measurement of air flow velocity, a fan with three speed levels was used. The data collection was carried out on 500 data. The average value was determined by equation (1):

$$\bar{x} = \frac{x1+x2\ldots+xn}{n} \tag{1}$$

where x represents the mean for n measurements, x1 indicates the value of the first measurement, x2 indicates the value of the second measurement and xn indicates the value of the nth measurement. Meanwhile, the standard deviation is a value that indicates the degree (degree) of variation in a data set or a measure of the standard deviation of the mean. The formula for standard deviation (SD) is shown in equation (2):

$$\text{SD} = \sqrt{\frac{\sum_{i=1}^{n}(Xi-\bar{x})^2}{(n-1)}} \tag{2}$$

where xi indicates the number of desired values, x indicates the average of the measurement results, and n indicates the number of measurement data. Furthermore, %error indicates a device error compared to the standard device. The %error formula is shown in equation (3):

$$\%\text{Error} = \frac{x_{std}-x_{uut}}{x_{std}} \text{ x } 100\% \tag{3}$$

where x_std indicates the reading value of the standard device (Fluke) and x_uut indicates the value of the design reading.

III. RESULT

In measuring the air temperature, the Fluke DPM4 Parameter Tester was used as a comparison device. After 60 minutes of measurement, the measurement data stored on the sdcard was read on a computer using the excel program and an analysis was carried out to find out the average value of each parameter T1 to T7. Table 1 and Figure 4 show the average results of the temperature distribution monitoring device and standards. We found the largest error in the measurement of 2.08% at T1, 1.58% at T2, -2.73% at T3, 1.61% at T4, -1.07% at T5, -0.06% at T6, and -2.32% at T7. However, the error value is still less than 5%, indicating that the level of accuracy of the module is quite good (TABLE 1).

TABLE 1

Comparison of measurements of T1, T2, T3, T4, T5, T6 and T7 monitoring devices for temperature distribution and standards on blood bank temperature setting (4°C).

Parameter	Mean (°C)	Standar (°C)	Error (%)
T1	3.56	3.63	2.08
T2	3.58		1.58
T3	3.73		-2.73
T4	3.57		1.61
T5	3.67		-1.07
T6	3.63		-0.06
T7	3.72		-2.32

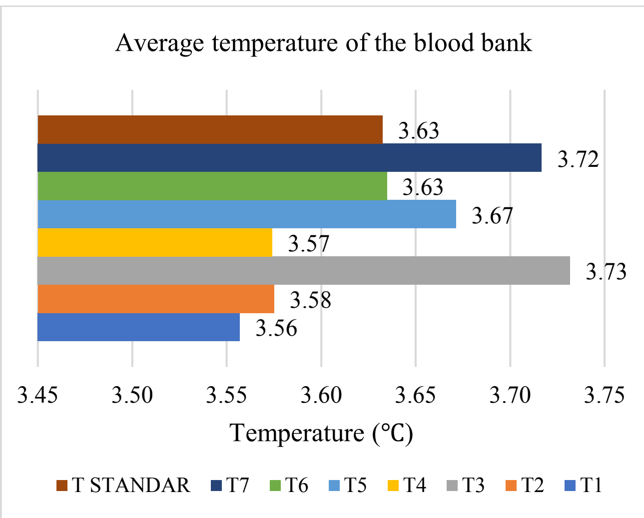

Figure 1. Comparison of measurements of T1, T2, T3, T4, T5, T6 and T7 between temperature monitoring devices and standards on blood bank temperature setting (4°C).

FIGURE 4 shows the average temperature sensor measurement values T1 to T7 of the module and compared with standard at 4°C temperature settings. The highest difference value is T3, which is 0.1°C or 2.73% of the standard value. The error value is less than 5%. Therefore, it can be concluded that the sensor module accuracy value is good. FIGURE 5 displays the results of reading the temperature measurement data T1 to T7 that has been stored on the SD card. The measurements were taken for 60 minutes. As can be seen in the figure, at the measured blood bank temperature, T1 is closest to the setpoint, followed by the second point closest to the setpoint is T2 and T4. Meanwhile, the points farthest from the setpoint in order are T5, T7 and T6 but the seven sensors are still within the normal temperature range of 2 - 6 °C. Hence, it can be concluded that the Kirsch blood bank has a fairly good temperature distribution.

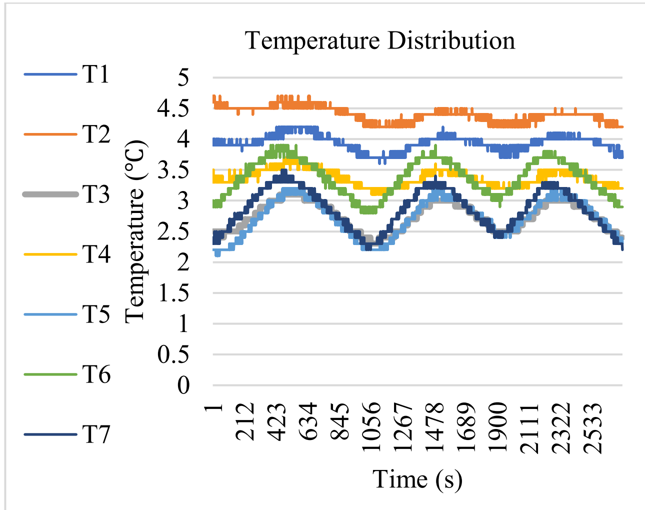

Figure 2. Line graph of temperature distribution T1-T7 on a temperature monitoring device at blood bank temperature setting (4°C).

	A	B	C	D	E	F	G	H
1	Date/Time	T1	T2	T3	T4	T5	T6	T7
3239	30-Ags-2022 16:01:13	4	4.6	2.5	3.3	2.2	2.9	2.4
3240	30-Ags-2022 16:01:14	4	4.7	2.5	3.4	2.2	2.9	2.3
3241	30-Ags-2022 16:01:15	3.9	4.6	2.5	3.3	2.2	2.9	2.4
3242	30-Ags-2022 16:01:17	3.9	4.6	2.5	3.5	2.2	3	2.4
3243	30-Ags-2022 16:01:18	4	4.6	2.5	3.5	2.2	2.9	2.4
3244	30-Ags-2022 16:01:19	4	4.6	2.5	3.4	2.2	2.9	2.4
3245	30-Ags-2022 16:01:21	3.9	4.7	2.5	3.4	2.2	2.9	2.3
3246	30-Ags-2022 16:01:22	4	4.6	2.5	3.3	2.2	2.9	2.3
3247	30-Ags-2022 16:01:23	4	4.7	2.5	3.4	2.2	2.9	2.3
3248	30-Ags-2022 16:01:25	4	4.7	2.5	3.3	2.2	2.9	2.3
3249	30-Ags-2022 16:01:26	3.9	4.6	2.5	3.4	2.2	2.9	2.5
3250	30-Ags-2022 16:01:27	4	4.7	2.5	3.3	2.2	2.9	2.4

Figure 6. display the contents of the measurement results file in the excel program

FIGURE 6 shows the blood bank compartment temperature measurement data stored by the module on the SD card memory. Files in csv format, read on a computer using the excel program. The data stored on the sdcard contains some data such as date of the data, complete with hours, minutes and seconds as well as data from temperature sensor measurements T1 to T7 in degree units (°C).

Figure 7. Blynk application display for wireless temperature monitoring

FIGURE 7 is a display of the blynk application used by researchers to remotely monitor the temperature of the blood bank compartment. In addition to monitoring, researchers used Blynk as a warning when the temperature in the compartment is outside the normal temperature range of 2 - 6°C.

IV. DISCUSSION

The results show that the proposed design can be used to measure temperature parameters in blood banks. This module used DS18B20 to measure air temperature. All temperature parameters are displayed on a 3.5 inch TFT screen and measurement data were sent to the blynk application using an internet connection so that it can be monitored by several devices directly. The measurement results were displayed on the blynk application page in the form of real-time graphs.

The smallest error in air temperature measurement with the DPM4 tester and the highest errors obtained were 2.08% at T1, 1.58% at T2, -2.73% were T3, 1.61% at T4, -1.07% at T5, -0.06% at T6, -2.32% at T7. After being compared with standard equipment, the device was used to measure the temperature spread in the Kirsch brand blood bank and the average temperatures obtained were 3.56°C at T1, 3.58°C at T2, 3.73°C at T3, 3.57°C at T4, 3.67°C at T5, 3.63°C at T6, and 3.72°C at T7. Based on the results of the comparison of the measurement results of the module with these standards, the error value obtained is not more than 5%, so it can be stated that the designed temperature monitoring device has met the standard requirements. The error value obtained from using the ds18b20 sensor is still smaller than using the K-Type thermocouple sensor, such as research conducted by Aponte-Roa et al [28] which obtained an error of 3% while using K-Type sensor and MAX6675 to perform cold-junction compensation and digitalizes the signal coming from a K-Type thermocouple. Using the ds18b20 sensor can also save on the use of I/O pins on the microcontroller by using parasite mode [29]. The limitation of this research is that sending sensor readings to the blynk application requires an internet connection, so that if the internet connection is lost, the sensor readings cannot be sent.

The development of a temperature distribution monitoring device with SD card storage can be applied to verify the condition of the blood bank both during calibration and routine inspections. Implementation of the use of the blynk application can facilitate the process of recording data and monitoring remotely by users. Wireless communication was used in the condition of a wide range of application, especially the devices which need more mobility and the area that it is not convenient for people to get to the scene [30].

V. CONCLUSION

This study shows that the device can be used for monitoring the distribution of temperature in the blood bank using IoT. This study aims to measure the temperature distribution in blood banks using 7 DS18B20 sensors by sending data to devices that have the Blynk application installed to facilitate temperature monitoring in each compartment of the blood bank. The device is also equipped with data storage to SD card memory. The use of blynk can help monitor compartment temperature remotely. The existence of an alarm also helps the user to find out more quickly when there is a temperature deviation that exceeds the normal range. It can also be concluded that the system can be used to verify the condition of the blood bank and send sensor readings to the blynk application using an internet connection. The addition of a real-time clock is very useful for displaying real-time time on the TFT screen and entering time data on each data sent to the SD card memory.

REFERENCES

[1] F. Oktavia, R. Muhiddin, and M. Arif, "Analysis Of Erythrocyte Indices In Stored Packed Red Cells At The Blood Bank Of Dr. Wahidin Sudirohusodo Hospital," *Indones. J. Phatology Med. Lab.*, vol. 16, no. 3, pp. 55–104, 2017, [Online]. Available: http://journal.unair.ac.id/download-fullpapers-IJCPML-12-3-08.pdf.

[2] J. L. Osterman and S. Arora, "Blood Product Transfusions and Reactions," *Hematol. Oncol. Clin. North Am.*, vol. 31, no. 6, pp. 1159–1170, 2017, doi: 10.1016/j.hoc.2017.08.014.

[3] C. G. Koch *et al.*, "Real Age: Red Blood Cell Aging During Storage," *Ann. Thorac. Surg.*, vol. 107, no. 3, pp. 973–980, 2019, doi: 10.1016/j.athoracsur.2018.08.073.

[4] Ministry of Health, *REGULATION OF THE MINISTER OF HEALTH OF THE REPUBLIC OF INDONESIA NUMBER 91 OF 2015 CONCERNING STANDARDS FOR BLOOD TRANSFUSION SERVICES*. Indonesia, 2015, p. 290.

[5] A. A. Saputro *et al.*, "Journal of Hemoglobin Medical Laboratory Analyst in Whole Blood Components of Donor Blood," vol. 6, no. 2, pp. 50–56, 2021.

[6] World Health Organization, "Clinical Transfusion Practice," *Clin. Transfus. Pract. Guidel. Med. Interns*, pp. 1–42, 2012.

[7] D. Wang, L. Zhang, and S. Zhang, "Evaluation model of refrigerator cooling performance," *Proc. 2017 IEEE 2nd Adv. Inf. Technol. Electron. Autom. Control Conf. IAEAC 2017*, pp. 1565–1569, 2017, doi: 10.1109/IAEAC.2017.8054276.

[8] AMERICAN ASSOCIATION OF BLOOD BANKS, *FOR BLOOD BANKS AND TRANFUSION SERVICE*. 1974.

[9] P. Saragih, I. Adhayanti, Z. Lubis, and H. Hariman, "Effect of storage

time of Packed Red Cells (PRC) on changes in hemoglobin, hematocrit, and plasma glucose levels at H. Adam Malik Hospital, Medan, Indonesia," *Med. Sci. Dig.*, vol. 10, no. 2, pp. 501–505, 2019, doi: 10.15562/ism.v10i2.415.

[10] W. N. Rahmah, "The Effect Storage Of Blood Bags on Hemoglobin Levels In The Blood Donor Unit PMI Palangka Raya," 2013.

[11] WHO, "The Blood Cold Chain," *Blood Cold Chain*, p. 74, 2002.

[12] J. Sains and D. T. L. Medik, "The Effect of Storage Time on Hemoglobin Levels in Donor Blood Bags at the Blood Bank Santa Maria Hospital Pekanbaru," *J. Sains dan Teknol. Lab. Med.*, vol. 4, no. 2, pp. 32–38, 2019, [Online]. Available: http://jurnal.akjp2.ac.id/ojs/index.php/jstlm/article/view/44/26.

[13] C. M. Vancea and L. Viman, "Wireless data logger for thermal validation systems," *2011 IEEE 17th Int. Symp. Des. Technol. Electron. Packag. SIITME 2011 - Conf. Proc.*, pp. 295–298, 2011, doi: 10.1109/SIITME.2011.6102739.

[14] K.-Y. Chen and Y.-C. Shaw, "Applying back propagation network to cold chain temperature monitoring," *Adv. Eng. Informatics*, vol. 25, no. 1, pp. 11–22, Jan. 2011, doi: 10.1016/j.aei.2010.05.003.

[15] "Sensor Integrated Antenna Design for Applications in Cold Chain Logistic Services." .

[16] J. M. Belman-Flores and A. Gallegos-Muñoz, "Analysis of the flow and temperature distribution inside the compartment of a small refrigerator," *Appl. Therm. Eng.*, vol. 106, pp. 743–752, 2016, doi: 10.1016/j.applthermaleng.2016.06.065.

[17] V. C. Falcón, Y. V. V. Porras, C. M. G. Altamirano, and U. Kartoglu, "A vaccine cold chain temperature monitoring study in the United Mexican States," *Vaccine*, vol. 38, no. 33, pp. 5202–5211, 2020, doi: 10.1016/j.vaccine.2020.06.014.

[18] F. Azis, S. Wardhana, and D. Titisari, "Analysis of Temperature Distribution in Blood Banks Through Storage of Measurement Results with IoT Monitoring in the Blood Donor Unit of PMI Surabaya," vol. 3, no. 4, 2021.

[19] J. P. Sigle *et al.*, "Temperature-sensitive indicators for monitoring RBC concentrates out of controlled temperature storage," *Am. J. Clin. Pathol.*, vol. 144, no. 1, pp. 145–150, 2015, doi: 10.1309/AJCPN7L9RTTPNNRW.

[20] P. Li, Y. Zhou, X. Zeng, and T. F. Yang, "A design of the temperature test system based on grouping DS18B20," *ICIEA 2007 2007 Second IEEE Conf. Ind. Electron. Appl.*, pp. 188–191, 2007, doi: 10.1109/ICIEA.2007.4318396.

[21] Andreas, C. R. Aldawira, H. W. Putra, N. Hanafiah, S. Surjarwo, and A. Wibisurya, "Door security system for home monitoring based on ESp32," *Procedia Comput. Sci.*, vol. 157, pp. 673–682, 2019, doi: 10.1016/j.procs.2019.08.218.

[22] A. R. Nimodiya and S. S. Ajankar, "A Review on Internet of Things," *Int. J. Adv. Res. Sci. Commun. Technol.*, vol. 113, no. 1, pp. 135–144, 2022, doi: 10.48175/ijarsct-2251.

[23] Z. Lu, J. Li, and Z. Yao, "The reading/writing SD card system based on FPGA," *Proc. - 2010 1st Int. Conf. Pervasive Comput. Signal Process. Appl. PCSPA 2010*, pp. 419–422, 2010, doi: 10.1109/PCSPA.2010.107.

[24] N. N. Mahzan, A. M. Omar, S. Z. Mohammad Noor, and M. Z. Mohd Rodzi, "Design of data logger with multiple SD cards," *CEAT 2013 - 2013 IEEE Conf. Clean Energy Technol.*, pp. 175–180, 2013, doi: 10.1109/CEAT.2013.6775621.

[25] F. Xiong, "Wireless temperature sensor network based on DS18B20, CC2420, MCU AT89S52," *Proc. 2015 IEEE Int. Conf. Commun. Softw. Networks, ICCSN 2015*, pp. 294–298, 2015, doi: 10.1109/ICCSN.2015.7296172.

[26] E. Whaites, "Using the ESP32 microcontroller for data processing," *Essentials Dent. Radiogr. Radiol.*, vol. 5, pp. 1–493, 2013, doi: 10.1109/CarpathianCC.2019.8765944.

[27] R. T. Hasanat, M. D. Arifur Rahman, N. Mansoor, N. Mohammed, M. S. Rahman, and M. Rasheduzzaman, "An IoT based Real-time Data-centric Monitoring System for Vaccine Cold Chain," *2020 IEEE East-West Des. Test Symp. EWDTS 2020 - Proc.*, 2020, doi: 10.1109/EWDTS50664.2020.9225047.

[28] D. A. Aponte-Roa, L. Benitez-Montalvan, and E. E. Henao-Bravo, "A low cost digital voltmeter with temperature-measuring and data logging," *I2MTC 2018 - 2018 IEEE Int. Instrum. Meas. Technol. Conf. Discov. New Horizons Instrum. Meas. Proc.*, pp. 1–5, 2018, doi: 10.1109/I2MTC.2018.8409798.

[29] D. Semiconductor, "DS18B20 Programmable Resolution 1-Wire Digital Thermometer," *Datasheet*, pp. 1–27, 2008.

[30] Y. Zhang, Z. S. Wang, and J. Li, "Design a wireless temperature measurement system based on NRF9E5 and DS18B20," *2010 Int. Conf. Meas. Technol. Mechatronics Autom. ICMTMA 2010*, vol. 1, pp. 910–913, 2010, doi: 10.1109/ICMTMA.2010.632.