ASEAN Engineering Journal

Full Paper

WET DIAPER DETECTION AND NOTIFICATION DEVICE TO ALERT THE BABY CARETAKER

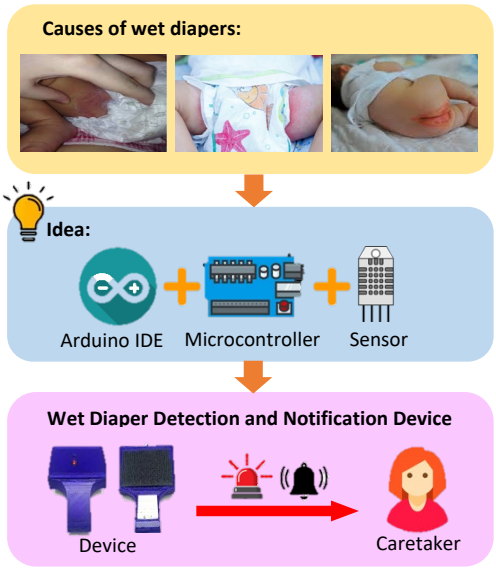
Dirman Hanafi Burhannuddin[a]*, Sulaiman Mazlan[b], Hisyam Abdul Rahman[b], Ruzairi Abdul Rahim[c]

[a]Instrumentation and Sensing Technology (InSeT) Research Group, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, Malaysia
[b]Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, 86400, Parit Raja, Johor, Malaysia
[c]School of Electrical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310, UTM Johor Bahru, Johor, Malaysia

Article history
Received
17 March 2021
Received in revised form
17 October 2021
Accepted
18 October 2021
Published online
28 February 2022

*Corresponding author
dirman@uthm.edu.my

Graphical abstract



Abstract

Diapers have been popular with parents for a past few decades now for protecting babies/children from urine when they urinate. However, there are some disadvantages when using diapers such as skin rash, irritation, and infection. Skin rashes can occur when the diaper is wet with urine and left to be used for a long time with the baby. This paper aims (i) to develop wet diaper detection and notification device for helping caretakers identify wet diaper conditions, (ii) to evaluate the performance of the wet diaper detection and notification device based on the response time to trigger notification after detecting wet diaper condition. The methods of this study were divided into four phases including project design, algorithm development, hardware development, and performance evaluation. This system serves to identify the wet diaper condition based on temperature and humidity values. DHT22 was selected as a main sensor and Arduino pro mini was selected as the microprocessor for this project. As the results, two wet diaper detection and notification devices have been designed and fabricated. Comparisons have been made to evaluate the performance between the first and second versions of the devices. The performance of second version device resulting better response time with 1700ms to notify the caretaker when detecting the wet diaper condition.

Keywords: Arduino pro mini, DHT22, Humidity detection, Temperature detection, Wet diapers.

1.0 INTRODUCTION

Demand for childcare centers is growing every year [1]. This is also supported by the trend of husband and wife working, so they have to leave their baby/children in childcare centers while they work. These baby/children will be cared by the babysitter as long as they are in the children's care center. Sometimes, one the babysitter should take care more than one baby/child. This causes them to be unable to give full attention to each of the baby/child. Diapers have been popular with parents for a past few decades now [2]. For protecting babies/children from urine when they urinate, parents or caretaker of babies/children will usually use diaper on them. There is no denying that the diapers are extremely convenient and have simplified the life of parents of this generation. Diaper is convenient to use because it is easy to find, there is no hassle to wash it, and there is no concern about the urine leakage. However, there are some disadvantages to using diapers for babies/children.

Some of its disadvantages are skin rash, irritation and infection [3, 4, 5, 6]. If the baby/child urinate, this will cause the diaper to get wet. If wet diapers are left on the baby for longer,

bacteria will breed in wet diapers and can cause rashes. Even more, babies/children have soft skin, so that in wet conditions and in contact with harsh diaper material will be able to cause baby's skin wounds and irritation [7, 8]. In addition, diaper manufacturers also often use synthetic fibers, dyes, or other harsh chemical products to make diapers. All of these harsh chemicals will easily damage the sensitive skin of the wet baby, so that it will experience allergies [9].

At present there is smart diaper in the market that are able to give information the diaper condition [10, 11, 12], but the price is quite expensive and also consists of several supporting equipment such as cameras, and others. Sometimes it is not familiar for some users. For that reason, this study will address to design a wet diaper condition checker device and provide information to baby caretakers with simple components and more affordable prices. The device able to detect the condition of a wet diaper and give notification to parents/babysitter/ caretaker. The DHT 22 sensor is proposed to be used in this study due to its ability to measure humidity and temperature condition of the diaper. This paper aims to develop wet diaper detection and notification device for helping caretakers identify wet diaper conditions, and to evaluate the performance of the wet diaper detection and notification device based on the response time to trigger notification after detecting wet diaper condition.

2.0 METHODOLOGY

The development of wet diaper detection and notification device was divided into four phases in order to achieve the project objectives. Figure 1 shows the process flow used for this project.

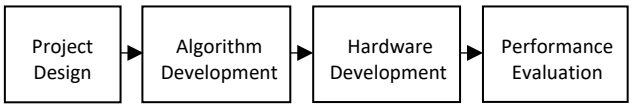


Figure 1 General idea for developing wet diaper detection and notification device

Phase 1 focuses on the project design including the listing of important electronic components and the design of the system for the wet diaper detection and notification device. Phase 2 involves the development of programming algorithms for the entire system of the device including the integration between the sensor and the notification alarm system. Phase 3 described the hardware development of wet diaper detection and notification device including the design criteria that was suitable to be used with the diaper. Finally, the performance of the developed device was evaluated in Phase 4.

2.1 Project Design

The selection of the suitable electronic components was important in order to develop the wet diaper detection and notification device. The systems of the device were divided by three part which were input, process, and output system. Figure 2 and Figure 3 show the block diagram and the circuit connection of the wet diaper detection and notification systems.

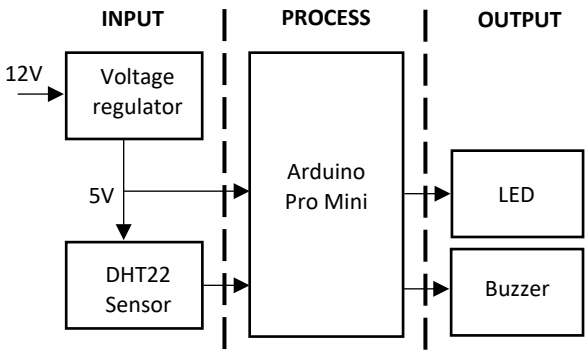


Figure 2 Block diagram of wet diaper detection and notification system

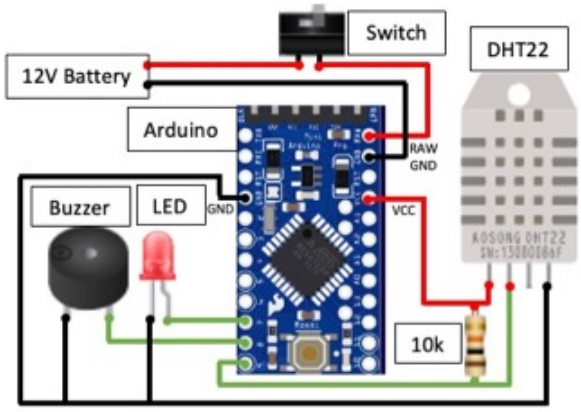


Figure 3 Circuit connection of wet diaper detection and notification system

The input components of wet diaper detection and notification device consist of two electronic components which were sensor and voltage regulator. This system serves to provide sound notification when identifying wet diaper condition based on temperature and humidity values. Therefore, DHT22 sensor, a low-cost digital sensor was selected as the main sensor of this project where it serves to measure temperature and humidity of an enclosure and generates a digital signal on the data pin. The temperature measurement has an accuracy of ± 0.5 °C and the relative humidity measurement has an accuracy of 2-5% [13, 14, 15, 16]. The operating voltage for this sensor is 3-5 volts, therefore the voltage regulator was used to regulate 12 volts to 5 volts from the battery to supply the sensor.

The Arduino Pro Mini was used as a microcontroller for wet diaper detection and notification system where it serves as a processor to control the system based on the algorithms that have been developed. In addition, the Arduino Pro Mini was a low-cost microcontroller and has adequate I/O ports for this project. Arduino Pro Mini was based on ATmega328 where it was a low power CMOS 8-bit microcontroller and comes in 3.3 volts and 5 volts [17]. This project used 5 volts system, as it has twice the speed of instruction execution [18]. The function of the Arduino Pro Mini in this system is to process the temperature and humidity data from the DHT22 sensor and trigger the output components based on the conditions that have been set in the algorithm. Light-emitting diode (LED) and buzzer were categorized as output component for wet diaper detection and

notification device. These output components served to provide a notification alert for the user through flickering light and sound frequency.

2.2 Algorithm Development

The programming algorithm depends on the temperature and humidity values measured from the DHT22 sensor. In Malaysia, studies show that the maximum indoor temperature was 32.6 °C and annual relative humidity value was between 74 % to 86 % [19]. Diaper are usually used with baby where the normal body temperature of a baby was between is 36 °C to 37.4 °C [20]. This project used urine temperature and humidity of diaper to identify the diaper condition while being used with the baby. Since the temperature of the urine was the same as the body temperature and more than the room temperature, the algorithm in this system has set the temperature above 32.6 °C as a temperature benchmark. The algorithm also set the humidity value above 86 % as a humidity benchmark to identify diaper conditions. The algorithm for wet diaper detection and notification system was developed based on the flow chart illustrated in Figure 4.

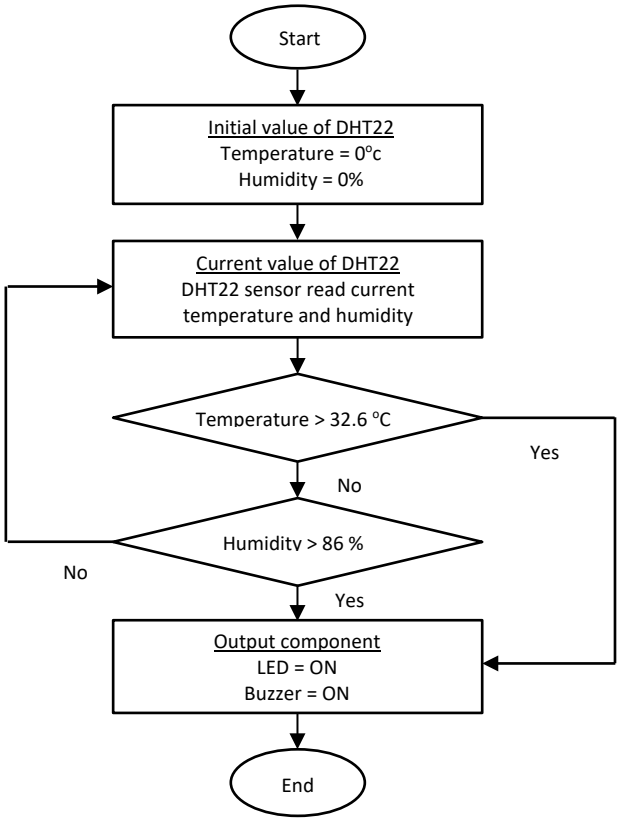


Figure 4 Flow chart of wet diaper detection and notification device system

The programming of algorithm was done using the Arduino IDE (Integrated Development Environment) software. The I/O pin connected to the DHT22 sensor was defined as the input while the I/O pin connected to the LED and buzzer were defined as the output in the Arduino algorithm. The algorithm starts by setting the initial value of DHT22 sensor equal to zero for both temperature and humidity. Then, the DHT22 sensor reads the current value of temperature and humidity from the diaper condition. If the temperature value exceeds 32.6 °C and humidity exceeds 86 %, the program will blink the LED and switch on the buzzer.

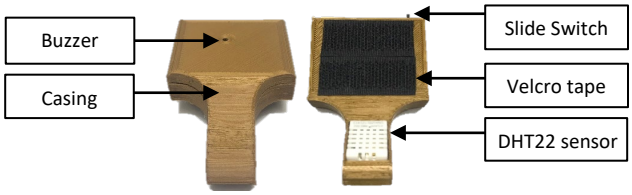
2.3 Hardware Development

The hardware of wet diaper detection and notification device has been designed and printed using a 3D printer. This device was designed to be compact so that it is suitable for use with diapers. This device is also designed to be placed on the diaper surface and Velcro tape has been used as an adhesive to attach the device on the diaper surface to facilitate the DHT22 sensor for identifying wet diaper condition. A switch was placed on the device to make it easier for the user to turn the device on and off.

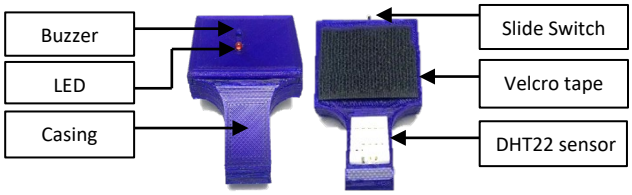
3.0 RESULTS AND DISCUSSION

3.1 Hardware

As the results, two versions of wet diaper detection and notifications device have been developed in this project for helping the baby caretaker to prevent babies from infection due to wet skin. The second version device was developed to improve the first version device in terms of compactness and effectiveness. Figure 5 shows the hardware of the wet diaper detection and notification device. This device has been used in conjunction with a baby wearing a diaper. Figure 6 shows the position of the device when used with baby. Table 1 shows the comparison of specifications between the two versions of the device.



(a) Device 1.0



(b) Device 2.0

Figure 5 Wet diaper detection and notification device

(a) Device position **(b)** Device with baby **(c)** Outside view

Figure 6 Position of the device when used with baby

Table 1 Specification of Wet Diaper Detection and Notifications Device

Specification	Wet Diaper detection and notifications device	
	Device 1.0	Device 2.0
Dimension (L x W x H)	52 x 88 x 17 (mm)	47 x 72 x 14 (mm)
Weight	35 (g)	28 (g)
Components	DHT22 sensor, Arduino Pro Mini, slide switch, 12V battery, Onboard LED, buzzer	DHT22 sensor, Arduino Pro Mini, slide switch, 12V battery, LED, buzzer
Delay time	1000ms	500ms

Abbreviations: L, Length; W, Width; H, Height;

Based on Table 1, differences have been made based on some specifications between version 1.0 and version 2.0 of the wet diaper detection and notification device. Device 2.0 has a smaller dimension size and has 20 % less of weight. This shows that Device 2.0 was more compact in terms of size and weight compared to Device 1.0. One external LED has been added to Device 2.0 to improve the sensitivity and practicality of the notification system. In addition, there was a difference in programming between both devices. The delay time was defined as the waiting time to start each programming cycle for DHT22 to read the current temperature and humidity of the diaper condition. The less value of delay time, the better the program response toward the diaper condition. However, if the delay time value was too small, it may cause the notification system to become unstable. Therefore, the value of delay time for Device 2.0 has been reduced by only 50% from 1000ms to 500ms in order to increase the system's response toward the diaper condition.

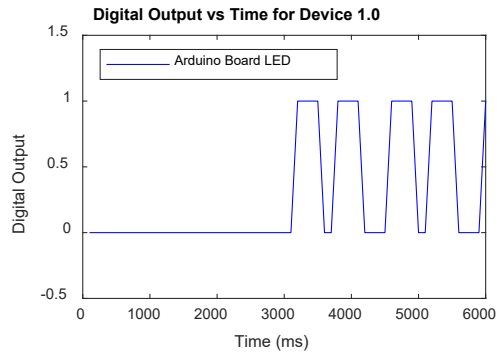
3.2 Performance of The Device

Both wet diaper detection and notification devices have four working conditions based on the algorithms that have been developed. As a result, these two devices work successfully based on all four working conditions to detect the wet diaper condition by notification through alarm sound. The experiment has been repeated five times to ensure the repeatability of the system. The working condition of the device has been tabulated in Table 2.

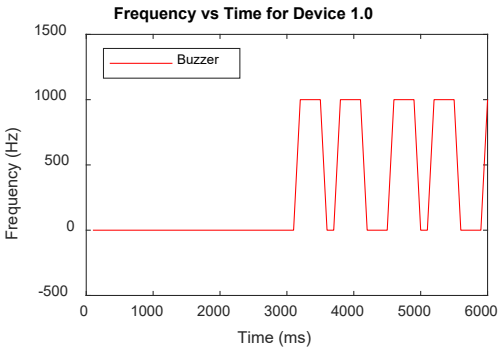
Performance of the wet diaper detection and notification devices has been evaluated based on the response speed to provide notification when detecting wet diaper condition. Data from the device has been captured from the digital output connection between microcontroller and the output system (LED and Buzzer). Figure 7 and Figure 8 show the output component versus response time graph for Device 1.0 and Device 2.0 respectively.

Table 2 Working Condition of Wet Diaper Detection and Notification Devices

Device 1.0				
Condition	**Temperature**	**Humidity**	**Arduino LED**	**Buzzer**
1	< 32.6 °C	< 86 %	OFF	OFF
2	< 32.6 °C	> 86 %	ON	ON
3	> 32.6 °C	< 86 %	ON	ON
4	> 32.6 °C	> 86 %	ON	ON
Device 2.0				
Condition	**Temperature**	**Humidity**	**LED**	**Buzzer**
1	< 32.6 °C	< 86 %	OFF	OFF
2	< 32.6 °C	> 86 %	ON	ON
3	> 32.6 °C	< 86 %	ON	ON
4	> 32.6 °C	> 86 %	ON	ON

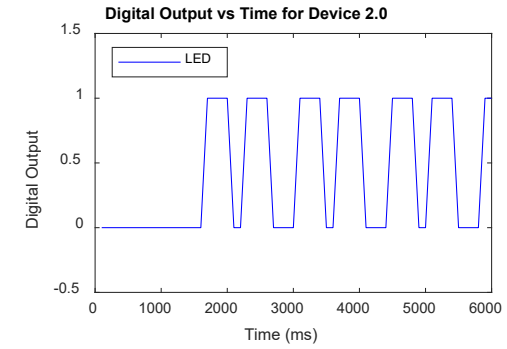


(a) Arduino Board LED

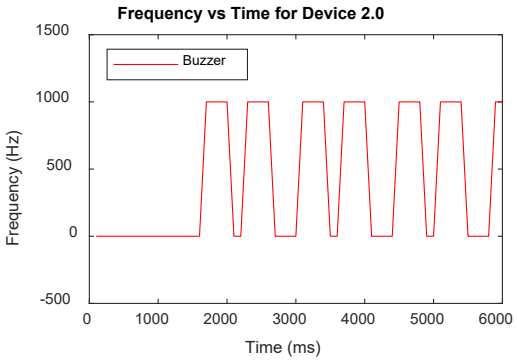


(b) Buzzer

Figure 7 Output graph for Device 1.0



(a) Device LED



(b) Buzzer

Figure 8 LED and buzzer output graph for Device 2.0

Based on Figure 7 and Figure 8, the performance of wet diaper detection and notification devices were evaluated between the range of 0ms to 6000ms. The digital output for LED has two values, where 0 indicated that LED was OFF while value of 1 indicated that LED was ON. Furthermore, the buzzer also has two frequency values which were 0Hz and 1000Hz that indicated the buzzer was in ON and OFF condition respectively. There was a difference between delay time and triggered time on devices. It was due to the additional time for the diaper to fully absorbed the urine before the sensor detects the humidity and the temperature condition of the diaper. As the results, Device 1.0 took 3200ms to trigger notification alarm while Device 2.0 took only 1700ms to trigger notification alarm after identifying wet diaper condition. The results shows that Device 2.0 has better response time performance where 43.8% faster than response time for Device 1.0. Therefore, Device 2.0 has been proposed to be used for helping the baby caretaker in order to prevent babies from infection due to wet skin.

4.0 CONCLUSION

In this study, two electronic wet diaper detection and notification device have been designed and fabricated. The devices have been installed on diaper and tested with baby to measure the performance of the device. In addition, a comparison has been made to evaluate the performance between the first and second versions of the wet diaper detection and notification devices. As the results, both devices functioned well to detect the wet diaper condition by notification through alarm sound. The second version device has better performance compared to the first version device due to it has a more compact design and resulting better response time to notify the baby caretaker regarding the wet diaper condition.

Acknowledgement

The authors would like to acknowledge the Research Management Centre (RMC) of Universiti Tun Hussein Onn Malaysia for their supports under project vot. no. H611.

References

[1] Mutalib, M.A., Saleh, N.S.S.N., and Masut, A. bin 2018. Quality Enhancement of Child Care Centres In Malaysia: An Analysis on Laws and Regulations. *Journal of Education & Social Sciences*. 9(1): 23–28.

[2] Shee, K. and Jagtap, V. 2019. Effect of Health Teaching on Knowledge and Practice of Postnatal Mother Admitted In Selected Hospital Regarding Using Diaper in Children to Prevent Systemic Bacterial Infection. *International Journal of Health Sciences and Research*. 9(7): 95–101.

[3] Yuan, C., Takagi, R., Yao, X.Q., Xu, Y.F., Ishida, K., and Toyoshima, H. 2018. Comparison of the Effectiveness of New Material Diapers versus Standard Diapers for the Prevention of Diaper Rash in Chinese Babies: A Double-Blinded, Randomized, Controlled, Cross-Over Study. *BioMed Research International*. 2018: 1-6. DOI : https://doi.org/10.1155/2018/5874184

[4] O'Connor, R.J., Sanchez, V., Wang, Y., Gibb, R., Nofziger, D.L., Bailey, M., et al. 2019. Evaluation of the Impact of 2 Disposable Diapers in the "Natural" Diaper Category on Diapered Skin Condition. *Clinical Pediatrics*. 58(7): 806–815. DOI : https://doi.org/10.1177/0009922819841136

[5] Šikić Pogačar, M., Maver, U., Marčun Varda, N., and Mičetić-Turk, D. 2018. Diagnosis and management of diaper dermatitis in infants with emphasis on skin microbiota in the diaper area. *International Journal of Dermatology*. 57(3): 265–275. DOI : https://doi.org/10.1111/ijd.13748

[6] Carr, A.N., DeWitt, T., Cork, M.J., Eichenfield, L.F., Fölster-Holst, R., Hohl, D., et al. 2020. Diaper dermatitis prevalence and severity: Global perspective on the impact of caregiver behavior. *Pediatric Dermatology*. 37(1): 130–136. DOI : https://doi.org/10.1111/pde.14047

[7] Umachitra, G. and Bhaarathidhurai 2012. Disposable baby diaper--a threat to the health and environment. *Journal of Environmental Science & Engineering*. 54(3): 447–452.

[8] Blume-Peytavi, U. and Kanti, V. 2018. Prevention and treatment of diaper dermatitis. *Pediatric Dermatology*. 35. DOI : https://doi.org/10.1111/pde.13495

[9] Coughlin, C.C., Eichenfield, L.F., and Frieden, I.J. 2014. Diaper Dermatitis: Clinical Characteristics and Differential Diagnosis. *Pediatric Dermatology*. 31(s1): 19–24. DOI : https://doi.org/10.1111/pde.12500

[10] Arpitha, M., Dsouza, R., Shreya, K., and Ranganatha, K. 2020. Smart Diaper Moisture Detection System using IoT. *International Research Journal of Engineering and Technology*. 7(4): 5778–5782.

[11] Sidén, J., Koptyug, A., and Gullikson, M. 2004. The smart diaper moisture detection system. *IEEE MTT-S International Microwave Symposium Digest*. 2: 659–662.

[12] Hardawar, D. 2019. Pampers gets into smart diapers with Lumi | Engadget..

[13] Molina, J.R., Nakama, V.L., and Lefebvre, G. 2020. A low-cost measurement device for recording perceptions of thermal comfort. *Journal of Physics: Conference Series*. 1433 012006.

DOI : https://doi.org/10.1088/1742-6596/1433/1/012006

[14] Bogdan, M. n.d. How to Use the DHT22 Sensor for Measuring Temperature and Humidity with the Arduino Board. *ACTA Universitatis Cibiniensis*. 68(1): 22–25. DOI : https://doi.org/10.1515/aucts-2016-0005

[15] Abdulrazzak, I.A.A., Bierk, H., and Ahmed, L. 2018. Humidity and temperature monitoring. *International Journal of Engineering and Technology*. 7(4): 5174–5177.

[16] Adhiwibowo, W., Daru, A.F., and Hirzan, A.M. 2020. Temperature and Humidity Monitoring Using DHT22 Sensor and Cayenne API. *Jurnal Transformatika*. 17(2): 209–214. DOI : https://doi.org/10.26623/transformatika.v17i2.1820

[17] Louis, L. 2016. Working Principle of Arduino and Using it as a Tool for Study and Research. *International Journal of Control, Automation, Communication and Systems*. 1(2): 21–29. DOI : https://doi.org/10.5121/ijcacs.2016.1203

[18] Payal, D. and Sushilkumar, R. 2019. Remotely Monitoring of Health using Fitband. *International Journal of Engineering and Advanced Technology*. 9(1): 3283–3285. DOI : https://doi.org/10.35940/ijeat.A1445.109119

[19] Jamaludin, N., Mohammed, N.I., Khamidi, M.F., and Wahab, S.N.A. 2015. Thermal Comfort of Residential Building in Malaysia at Different Micro-climates. *Procedia - Social and Behavioral Sciences*. 170: 613–623. DOI : https://doi.org/10.1016/j.sbspro.2015.01.063

[20] Zakaria, N.A., Saleh, F.N.B.M., and Razak, M.A.A. 2018. IoT (Internet of Things) Based Infant Body Temperature Monitoring. in: 2018 2nd Int. Conf. BioSignal Anal. Process. Syst., 148–153. DOI : https://doi.org/10.1109/ICBAPS.2018.8527408