

## RESEARCH ARTICLE

## OPEN ACCESS

Manuscript received May 18, 2022; revised June 20, 2022; accepted July 10, 2022; date of publication July 29, 2022

Digital Object Identifier (DOI): <https://doi.org/10.35882/jeeemi.v4i3.227>

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# Sensor Accuracy Analysis on Incubator Analyzer to Measure Noise and Airflow Parameters

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**ABSTRACT** Infant incubators are equipment to maintain a stable body temperature for premature babies. Premature babies need room conditioning that is close to conditions in the womb. Room conditioning is carried out in a baby incubator by providing a stable temperature, relative humidity, and measured air flow. This parameter must be controlled so as not to exceed the threshold that will harm the baby. Periodic calibration should be applied to the infant incubator to monitor its function. To ensure the availability of baby incubators according to service standards, it is necessary to conduct test (calibrate) using an incubator analyzer. The purpose of this study is to conduct further research on the incubator analyzer that focuses on discussing the accuracy of noise and airflow sensors with the gold standard. In this study, an experiment was carried out for the sensitivity level of several sensors that had been treated by giving treatment to sensors to choose sensors with good sensitivity to be assembled into one in the incubator analyzer module. The noise sensors (KY-037 and Analog Sound Sensor V2.2) were further compared with the values on the sound level meter and the airflow sensor (D6F-V03A1) was compared with the anemometer. Sensors whose values are close to the comparison values were selected to be integrated into the incubator analyzer module. The incubator analyzer module used Arduino Mega2560 as a data processor and was equipped with an SD Card for the data storage. The built incubator analyzer module was also compared to the Fluke INCU II gold standard for data analysis. The results showed that the Analog Sound Sensor V2.2 had the highest error value (-4.6%) at 32°C and the D6F-V03A1 had the ability to measure sensitivity, where the results were more accurate than INCU II. Based on the error value of the noise sensor, the V2.2 sensor can be applied to measure noise in the baby incubator and the D6F-V03A1 airflow sensor produced an accuracy of up to 3 digits behind the comma which is more accurate than the standard module. The results of the INCU analyzer from this study can be used to calibrate the baby incubator, so that the certainty of the feasibility of the baby incubator is guaranteed. This research can be used as a reference for other researchers who will develop research on incubator analyzers in the future.

**INDEX TERMS** Incubator Analyzer, Noise, Air Flow, TFT Display

## I. INTRODUCTION

The health and safety of newborn babies is definitely a major focus for all pregnant women. This certainly cannot be separated from various possible problems or risks that arise, for example, such as the birth of a premature baby. According to WHO (World Health Organization), 15 million babies are born prematurely every year and more than 1 million babies die every year due to complications of premature birth [1][2][3]. Unstable newborns weighing 2000 g or less at birth, or stable newborns weighing less than 2000 g who cannot be given the kangaroo method of care, should be cared for in a thermo-neutral environment either under radiant heating or in an incubator [4]. An infant incubator or neonate incubator is a device consisting of a rigid box like a

cage in which the baby can be kept in a controlled environment for medical care, J Perez concluded that airflow is helpful in the care of premature babies [5][6]. Virat Plangsangmas conducted a study on infant incubators used in hospitals in Thailand. This situation raised the question of whether the value of physical quantities such as sound pressure or temperature in the incubator is still in accordance with the requirements of international standards. The SPL (Sound Pressure Level) result of this study is lower than 60 dBA, which is within the tolerance limits specified in International Electrotechnical Commission (IEC) 60601-2-19. This research is useful for investigating hearing loss in infants [7]. Furthermore, Cardoso, S conducted a study evaluating the physiological and functional effects resulting

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Vol. 4, No. 3, July 2022, pp: 135-143

from noise exposure in low birth weight newborns in incubators in the neonatal unit. The result obtained that the neonates with low body weight in the incubator experienced physiological changes when facing discomfort due to environmental noise in the neonatal unit [8]. F. Fernández Zacarías further started that premature infants usually have to spend a long time in the incubator whose the excessive noise can have detrimental physiological and psychological effects on the neonate. In fact, incubator noise levels usually range from 45 to 70 dB but the difference in this is highly dependent on the noise measurement method used. Premature infants in incubators are exposed to noise levels that clearly exceed international recommendations even though these levels usually meet the limits set out in standard of IEC 60601-2-19:2009 (60 dBA) under normal conditions of use [9]. Neille, J., conducted a study aimed at identifying the sources of noise in three NICU (Neonatal Intensive Care Unit) in Johannesburg, South Africa to determine the noise level exposed to neonates in incubators at various positions in the NICU. These findings were then compared with the standards recommended by the American Academy of Pediatrics (AAP). Most noise is generated by humans, highlighting the need to develop awareness of the negative effects of noise in the NICU and to implement programs to reduce the noise. These findings further have important implications for neonatal care and highlight the importance of noise reduction and monitoring strategies in the NICU [10]. Fortes-Garrido, J further added that the effects of noise are very harmful to newborns, therefore he carried out a study assessing and characterizing noise levels in the neonatal intensive care unit (NICU) of a medium-sized hospital in Huelva City. Based on the research, it was obtained that the maximum noise levels measured for critical (C-in), C(out) and intermediate (I) were: 88.8 dBA, 97.2 dBA, and 92.4 dBA, respectively, while for the equivalent noise levels for the total measurement period (15 d) were 57.0 dBA, 63.7 dBA, and 59.7 dBA, respectively. The results showed that the values recommended by international bodies and institutions (AAP, WHO) are exceeded by a large margin, so it is very important to adhere to certain norms to reduce noise levels in the NICU through physical changes to the layout and raise the awareness of the health workers and visitors to encourage noise prevention in work and daily care conversations [11]. Shimizu then added conclusion obtained from his research that care providers should carefully assess the adverse effects of higher sound levels produced by different modes of respiratory support and take steps to ensure that premature infants are protected from exposure to noise that exceeds the optimal safe level [12]. In this case, the baby incubator has several parameters, namely temperature, humidity, air flow, and noise. The temperature inside the infant incubator is between 35.5 °C-37 °C, with a leakage rate of  $\pm 1$  °C outside temperature, humidity level of 70%, air flow rate of less than 0.35 ms, and noise level inside the incubator was more than 60 dBA [13]. Electro-medical equipment should be calibrated periodically and since the baby incubator is an electro-medical device, it must be calibrated as well. If calibration is not carried out, its malfunction can cause serious damage to the health of the newborn or even lead to the death of the newborn [14] [15][16][17]. Emre Ozdemir, et al. carried out analysis in 2014 concerning the reliability assessment of infant incubators and their analyzers. The study stated that if a baby incubator exceeds the normal limits of the agreed terms, it will have a negative impact on the baby, for example, if the air flow exceeds the normal limit, asphyxia will occur in the baby and if the noise exceeds the normal limit, dizziness will occur, blood pressure

will increase, and fluid in the baby's brain will decrease. In Turkey (the original country of the researcher), after calibration was conducted on several baby incubators using an incubator analyzer, parameters such as oxygen flow proved not to function properly. This showed that the relationship between the baby incubator and the incubator analyzer is very important [18]. The incubator analyzer ever made by Gamze Tilbe and Mehmet Yüksekaya in 2018 consisted of 3 parameters, namely temperature, humidity, and oxygen. The incubator analyzer they made used a DHT-22 sensor as a temperature and humidity sensor, an OOM 102 oxygen sensor as an oxygen sensor (measuring oxygen levels in the incubator), and a power source in the form of a rechargeable battery. There are 5 temperature measurement points on the device, data processing using Arduino Uno, and sensor readings displayed on the LCD (Liquid Crystal Display) screen, but in this study was not carried out to measure airflow and noise [19]. Incubator analyzer research was also conducted by G. Gnancy Subha and M. Fazilath in the same year (2018). They developed an incubator analyzer equipped with an automatic shutter opener. In this case, a tool was made to monitor temperature, humidity, detect toxic gases, and the position of the baby in the baby incubator. This tool used Arduino Uno as a data processor. The advantage of this tool is that it was connected to IoT (Internet of Things) so that at any time a toxic gas is detected in the baby incubator, it will immediately send a notification message to the nurse (nurse station) and the shutter on the baby incubator will automatically open or close. However, there are still some shortcomings, in which the parameters of the tool and the results of the research were not explained in detail [20][21]. Research on the incubator analyzer has also been carried out by other researchers with varying error results, but the airflow measurement error is still high with the results on the airflow sensor module having the highest error at 36°C and 37°C which is equal to 0.5%, and the highest error of the noise sensor module is 0.17% at 37°C of the setting temperature [22][23]. Research on incubator analyzer using Bluetooth with Android further was also done focusing on the parameters of humidity and air flow. The tool used was a DHT-22 sensor to detect humidity and an HC SR-04 ultrasound sensor to detect air flow. As a result, the largest error of DHT-22 produced was 1.28% and the largest error of the resulting ultrasound sensor HC SR-04 was 311.65% [24]. Vijay Anant Athavale conducted research to design an infant incubator analyzer that measures noise and air flow rate, the results of his research obtained an error value for the noise of 5.2% and flow rate measurements were able to reach 0.63 m/sec [25]. Peng Yin further studied the flow sensor to measure the PEFR (peak expiratory flow rate) and FEV1 (forced expiratory volume in 1 second) of the human body by applying the OMRON OMRON-D6F-V03A1 air flow sensor, which works in temperatures between -10°C to 60°C, with the ability to expel airflow at speeds between 0m/s to 3m/s and accuracy with  $\pm 10\%$  under working voltage of 3.15V-9.45V [26]. Professor John Webster said sleep apnea is a sleep disorder in which natural breathing is disturbed causing frequent awakenings. Frequent awakenings caused by this apnea prevent a person from achieving deep sleep which makes them tired throughout the day. In the study, the researcher made a tool for sleep apnea therapy using the OMRON-D6F-V03A1 sensor [27].

Based on the explanation above, it is necessary to conduct research to improve the performance of the air rate sensor and noise sensor in order to achieve a better accuracy value. This study aimed to design an infant incubator analyzer with a focus on the design of noise and air flow measurements. In this study,

experiments were carried out for the sensitivity level of several sensors that had been treated that is by giving treatment to the sensor to select a sensor with good sensitivity to be assembled into one in the incubator analyzer module. The results will be compared with the standard. In addition, monitoring can be viewed on a TFT (Thin film transistor liquid crystal display) screen and is equipped with graphs that will make it easier for users to monitor the baby incubator measurement process, and measurement data can be stored in SD (Secure Digital Card).

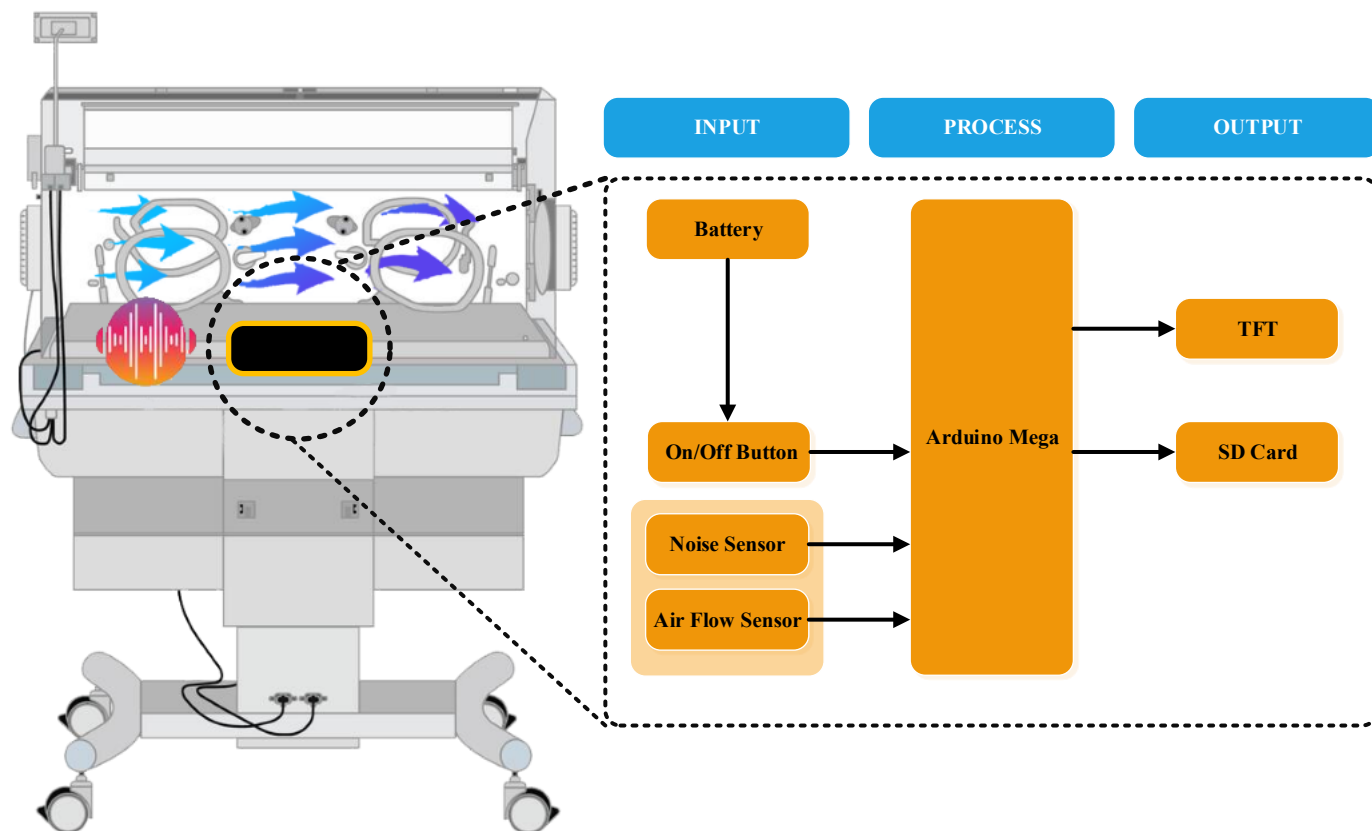
## II. MATERIALS AND METHODS

This research was conducted as experimental research. The author intended to conduct further research on noise sensors and

air flow sensors that would be used in the incubator analyzer module. Materials and methods are explained in the following sections.

### A. DATA COLLECTION

In this study, the researcher compared the design (INCUBATOR analyzer) and the standard INCUBATOR analyzer (Fluke Biomedical INCUBATOR II) as a comparison device. This research used KY-037 sensor and Analog Sound Sensor V2.2 to measure the noise in infant incubator and airflow of D6F-V03A1 sensor.



**FIGURE 1.** Measurement of air flow rate and noise level in infant incubator. By using a noise sensor and an air flow rate sensor. After the data is processed on the ATmega, the data will be displayed on the TFT and SD Card

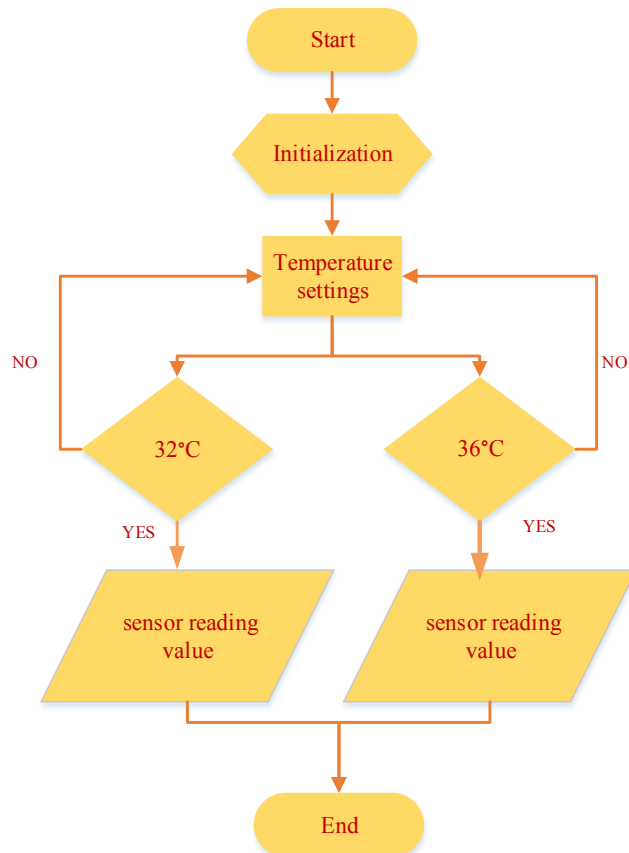
FIGURE 1 shows a diagram of the author's research workflow. Based on the image of the noise sensor, 2 sensors with different types were used, namely KY-037 and Analog Sound Sensor V2. In the air flow parameter, one sensor was used with the type of D6F-V03A1. These sensors were treated to determine which sensor is close to the standard results for each parameter. After the results were obtained, then the sensor with the best results was selected to be used in the incubator analyzer. Furthermore, the data from the sensor were processed using an ATmega microcontroller which were further displayed in the TFT in the form of numbers and graphs of the measurement results. In addition, the data can also be stored on the SD Card. An infant incubator was measured using the incubator analyzer module with a standard incubator analyzer

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Vol. 4, No. 3, July 2022, pp: 135-143

(INCUBATOR II Fluke). The results obtained from the incubator analyzer module were then compared with the standard incubator analyzer (INCUBATOR II Fluke), so that the accuracy of the incubator analyzer module can be determined. FIGURE 2 presents a flow chart of the process of measuring noise and air flow rate. In this process, when the device is turned on, the initialization process will take place, then the temperature is chosen for the infant incubator. Measurements were carried out in the baby incubator as a medium with a temperature setting of 32°C and 36°C. At the beginning, the infant incubator was turned on and set at 32°C, so it will be waited for first. The infant incubator will experience an overshoot temperature and then it will decrease until the temperature on the display was reached and stable. This lasted about 1 hour or so. After it was achieved, then the data storage of noise and air flow

rate were stored. Furthermore, measurements were also carried out at a setting temperature of 36°C through similar way, namely waiting for the temperature to be reached and stable. Noise data collection and air flow rate were taken at 2 temperature settings which later were seen whether there was an effect on the noise value and air flow rate.



**FIGURE 2** Flow Chart of the measurement of noise and air flow rate at 32 °C and 36°C of temperature setting



**FIGURE 3.** Display of Noise and Air Flow Parameter Values on the Incubator Analyzer Module

**FIGURE 3** shows the measurement value of noise and air flow in the baby incubator according to the temperature setting using the incubator analyzer module that has been made. The graph shown is a temperature graph. This graph is very helpful to know the stability of temperature measurement

## B. DATA ANALYSIS

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Vol. 4, No. 3, July 2022, pp: 135-143

Data analysis was carried out on every 120 data resulting from noise and air flow through 5 times measurements using the following formulas [28].

### • Mean/Average

Mean/average is the value or the result of dividing the amount of data taken or measured by the amount of data or the number of measurements. The following is the average formula in equation (1).

$$(\bar{X}) = \frac{\sum Xi}{n} \quad (1)$$

Based on equation (1),  $\bar{X}$  represents the average,  $\sum Xi$  indicates the number of data values, and  $n$  indicates the lots of data (1, 2, 3,...,  $n$ ).

### • Error (%)

Error is the amount of difference between the estimated value (approximate/approximate) and the actual value (exact). The following is the error formula in equation (2).

$$\%Error = \frac{(Xn - \bar{X})}{\bar{X}} \times 100\% \quad (2)$$

Based on the equation (2), the error is in percentage with  $Xn$  indicating the measured value and  $\bar{X}$  indicating the average setting value.

### • Standard Deviation

Standard deviation is a value that indicates the level (degree) of variation in a group of data or a standard measure of deviation from the mean. The following is the standard deviation formula in equation (3).

$$SD = \sqrt{\frac{\sum_{i=1}^n (Xi - \bar{X})^2}{(n-1)}} \quad (3)$$

Based on the equation (3), SD indicates the standard deviation,  $Xi$  indicates the data value,  $\bar{X}$  indicates the mean or average, and  $n$  indicates the lots of data.

### • Uncertainty

Uncertainty type A is the uncertainty that results from statistic calculations. The following is the formula for uncertainty type A in equation (4).

$$UA = \frac{SD}{\sqrt{n}} \quad (4)$$

Based on the equation (4), SD indicates the standard deviation and  $n$  indicates the lots of data.

## III. RESULTS

The sensors that have been selected will be assembled in a box as shown below. In **FIGURE 4**, you can see parts of the research module. The humidity sensor functions to detect humidity in the baby incubator, in which the sensor used was DHT 22 (Point A). T5 is a temperature sensor that functions to detect the temperature in the baby incubator, in which the sensor used was DS18B20 (Point B). The air flow sensor was used to measure the amount of air flow in the baby incubator, in which the sensor used was a sensor from OMRON with type D6F-V30A1 (point C). In this



case, the placement of the air flow sensor was designed in such a way that the air flow was not blocked by other components. The noise sensor was used to detect sound/noise in the baby incubator, in which the sensor used was Analog Sound Sensor V2.2 (Point D). In the display section, it used Nextion 5" TFT to display graphs and sensor readings, in this case, the temperature is displayed in graph form to make it easier to know the overshoot and the stability of the measurement temperature. As for the measurement values for noise and air flow rates, they are displayed in numerical or numeric form.

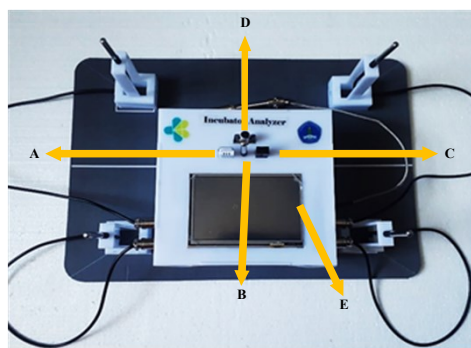


FIGURE 4. Incubator Analyzer Module Top View

#### A. NOISE PARAMETER RESULTS

Based on the results that have been obtained, it can be seen that the average sensor results to a comparator (sound level meter) are as follows.

TABLE 1 Average of sensor results on the sound level meter

Sound Level Meter (dB)	KY-037 (dB)	V2.2 (dB)
41	47.5	55.6
50	42.2	55.6
55	42.7	56.5
60	44	58.9
63	44.8	63
65	44.5	65.2

TABLE 1 is the results obtained from the KY-037 sensor and the Analog Sound Sensor V2.2 with 6 treatment conditions whose noise was measured with a sound level meter. The KY-037 sensor data and the Analog Sound Sensor V2.2 that have been generated in each treatment condition are averaged and then compared with the results on the sound level meter. FIGURE 5 shows a graph of the noise sensor using the V2.2 sensor and compared to the standard to look at which results on the graph is closer. Meanwhile, FIGURE 6 shows the graphic sensor using the KY-037 sensor and the results look far from the standard. This means that the V2.2 sensor is better than the KY-037 sensor. This is because the Analog Sound Sensor V2.2 is more sensitive to sound and the resulting value is closer to the value shown on the Sound Level Meter than the KY-037 sensor. Therefore, further measurements were done using V2.2 sensors.

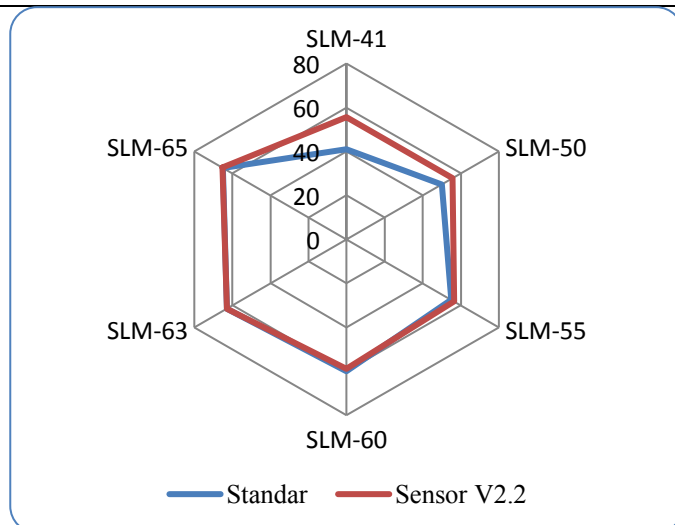


FIGURE 5. The radar graph shows the comparison of the average results of the V2.2 noise measurement and the Sound Level Meter Sensor (Standard).

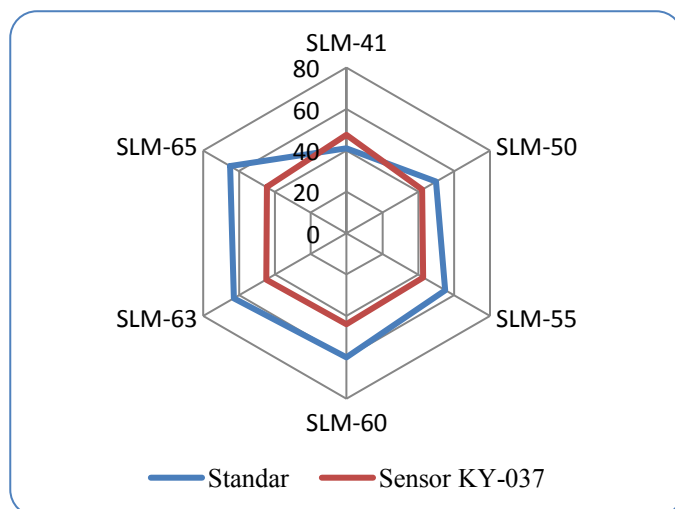
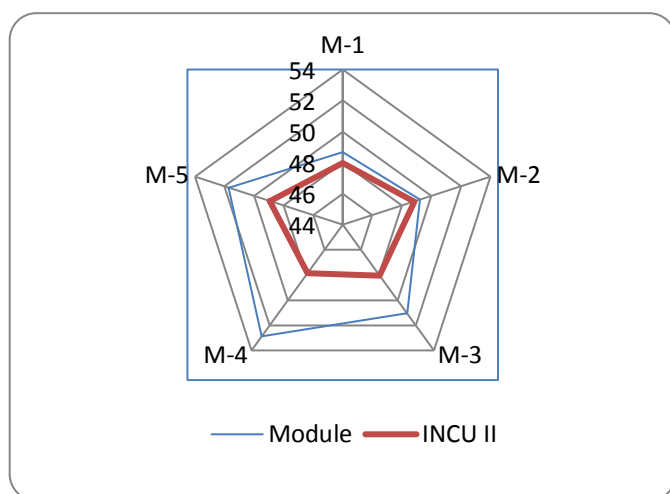


FIGURE 6. The radar graph shows the comparison of the average results of the KY-037 noise measurement and the Sound Level Meter Sensor (Standard)

TABLE 2 Measurement results of noise in a Infant incubator at 32°C setting temperature

Measurements	Modul (dB)	INCU II (dB)
1	47.98	48.675
2	48.85	49.225
3	48.05	51.05
4	47.87	52.875
5	48.93	51.725
Mean	48.34	50.71
STDEV	0.50	1.74
UA	0.22	0.78
Error (%)	-4.6	



**FIGURE 7.** The radar graph shows the comparison of the average noise measurement results and the INCU II at a temperature setting of 32°C

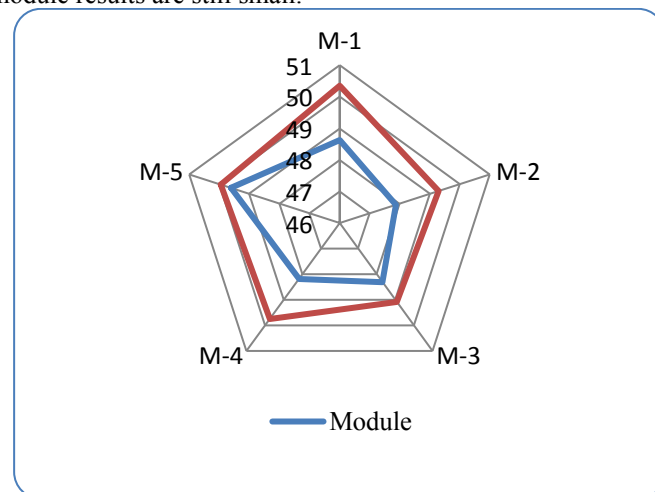
TABLE 2 and FIGURE 7 are the results of measurements in the Infant Incubator at a setting temperature of 32°C. Then, an analysis of each of the 120 data generated was performed 5 times. In the noise sensor of the incubator analyzer module, the mean value was 48.34dB, while the Fluke INCU II produced a mean value of 50.71dB. The standard deviation of the incubator analyzer module was 0.50 and the uncertainty was 0.23. The standard deviation of the INCU II Fluke was 1.74 and the uncertainty was 0.78. Based on the table, the error value was -4.6% with negative sign (-) because the average value of the incubator analyzer module results was smaller than the Fluke INCU II. However, by taking into account the uncertainty value, the research module was more precise or stable when used to measure.

**TABLE 3** Measurement results of noise in a Infant incubator at 36°C setting temperature

Measurements	Modul (dB)	INCU II (dB)
1	48.63	50.35
2	47.88	49.30
3	48.31	49.075
4	48.18	49.75
5	49.61	49.95
Mean	48.52	49.685
STDEV	0.66	0.50
UA	0.29	0.22
Error (%)	-2.3	

Based on TABLE 3 and FIGURE 8, in terms of the noise sensor of the incubator analyzer module, the mean value was 48.52dB, while the Fluke INCU II produced a mean value of 49.685dB. The standard deviation of the incubator analyzer module was 0.66 with the uncertainty was 0.29. The standard deviation of the INCU II Fluke was 0.50 with the uncertainty was 0.22. Based on the table, the resulting error value was -

2.3%, with a negative sign (-) because the average value of the incubator analyzer module results was smaller than the Fluke INCU II. However, judging from the uncertainty, the research module results are still small.



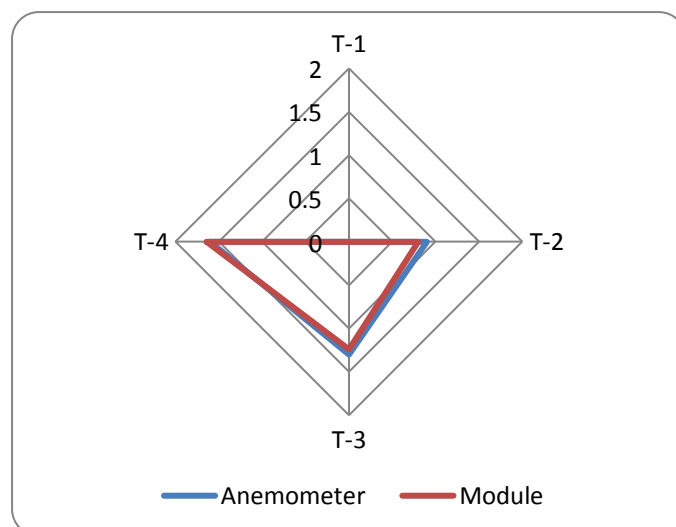
**FIGURE 8.** The radar graph shows the comparison of the average noise measurement results and the INCU II at a temperature setting of 36°C

## B. AIR FLOW PARAMETER RESULTS

Based on the results that have been obtained, it can be seen that the average sensor results to the comparator (anemometer) are as follows.

**TABLE 4** Average of sensor results to the anemometer

Anemometer (m/s)	Sensor (m/s)
0	0
0.9	0.795
1.3	1.24
1.6	1.64



**FIGURE 9** The radar graph shows the comparison of the results of the air flow rate measurement with the anemometer and the research module

TABLE 4 and FIGURE 9 are the results obtained from the air flow sensor D6F-V03A1 with 4 treatment conditions measuring the

air flow velocity using an anemometer. Sensor data D6F-V03A1 which have been generated in each treatment condition was averaged and then compared with the results on the anemometer. Based on the radar graph, it can be seen that the results coincided, indicating that the comparison between the anemometer and the sensor used in the module results is close to each other or indicating that the D6F-V03A1 sensor has good sensitivity.

**TABLE 5** Measurement results of air flow in a baby incubator at 32°C setting temperature.

Measurements	Modul (m/s)	INCUB II (m/s)
1	0.06	0.1
2	0.048	0.1
3	0.042	0.1
4	0.044	0.1
5	0.059	0.1
Mean	0.05	0.1
STDEV	0.008	-
UA	0.022	-

**TABLE 5** is the result of measuring the air flow in the infant incubator at a setting temperature of 32°C. Then, an analysis of each of the 120 data generated was performed 5 times. In the sensor module, the results had an average value of 0.05m/s, while the INCUB II Fluke produced an average value of 0.1m/s. If you look at the specifications on the INCUB II, the ability to measure air flow rates was 0.2 m/s to 2.0 m/s at 35°C. So the INCUB II was not capable of measuring airflow below 0.2 m/s and appeared only 0.1 m/s. Meanwhile, the research module was able to respond to the value of the air flow rate below 0.1 m/second. Even the research module was able to display measurement results with an accuracy of 3 digits behind the comma. These results indicate a better level of accuracy than previous studies of 2.7%.

**TABLE 6** Measurement results of air flow in a infant incubator at 36°C setting temperature

Measurements	Modul (m/s)	INCUB II (m/s)
1	0.137	0.1
2	0.138	0.1
3	0.138	0.1
4	0.136	0.1
5	0.14	0.1
Mean	0.138	0.1
STDEV	0.001	-
UA	0.0006	-

**TABLE 6** is the result of measuring the air flow in the infant incubator at a setting temperature of 36°C. The analysis was carried out on each of the 120 data generated 5 times. In the research module, the average value was 0.138 m/s, while the INCUB II Fluke produced an average value of 0.1m/s. As with the 32°C temperature setting, the INCUB II was only able to display a value of 0.1m/s. These results indicate a better level of accuracy than previous studies of 2.7%.

#### IV. DISCUSSION

The results showed that the proposed design can be used to measure the noise parameters and air flow rate in the infant incubator. The incubator analyzer module from this study

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Vol. 4, No. 3, July 2022, pp: 135-143

consists of several sensors that were used to measure 2 parameters, namely Analog Sound Sensor V2.2 to detect noise, and D6F-V03A1 to detect air flow rate in the baby incubator room. All parameters were displayed on the TFT screen in real-time. Then, the data will be saved on the SD Card in csv format. This study provides more development than previous research, this is because the incubator analyzer module that the author made has been supported by the results of treatment on the existing sensors and the incubator analyzer module was accompanied by a TFT display. Then, for measurements detected by the air flow sensor, the error was smaller than before. Based on the results of previous studies, it is equal to 311.65% and 0.5% for the measurement of air flow rate. From module testing, the results were then compared with the Fluke INCUB II to validate the measured parameters of the proposed model. The smallest error generated from the noise parameter was -2.3% at a temperature of 36°C, and the largest error was -4.6% at a temperature of 32°C. The air flow parameter was not calculated as an error because the INCUB II as a comparison was only able to display a value of 0.1 m/s. or in other words the research module was much more sensitive than the INCUB II module and 2.7% compared to previous studies. In this case, errors in measurement can be caused by a different sensor placement with the sensor placement on the INCUB II. So it is necessary to test some baby incubators. The limitation of this research is that storage is only limited to SD Card. It has not implemented IoT, so it cannot monitor the results remotely. Then, for the air flow sensor, there was also a difference in readings when the Arduino used a power source from the battery and a power source from the laptop. Based on this, it is necessary to make further considerations regarding the circuit and program selection for sensors. The module from this research can be used to calibrate the infant incubator which will determine the feasibility of an infant incubator. The research module can be implemented for general infant incubator measurements as well as for routine calibration processes. Temperature applications with graphical displays can make it easier to determine data collection on noise measurements and air flow rates. Further development can be implemented by implementing the android system or by implementing a modern control system to monitor measurements remotely [29][30].

#### V. CONCLUSION

The purpose of this study is to conduct further research on the incubator analyzer that focuses on discussing the accuracy of the noise and airflow parameter sensors against the gold standard. Based on the results that have been obtained when measuring or taking data from the module and comparison tool which is then carried out for data analysis, it can be concluded that based on the results of the noise sensor treatment of KY-037 and Analog Sound Sensor V2.2, this indicates that the Analog Sound Sensor V2.2 is better than KY-037 noise sensor. This is because the sensitivity and values displayed are closer to the results of the sound level meter. When measuring using a comparison tool (gold standard) Fluke INCUB II, the noise parameter has an average difference of 1.16 – 2.37dB against the Fluke INCUB II. The smallest error generated from the Analog Sound Sensor V2.2 noise sensor is -2.3% at a temperature setting of 36°C and the highest is -4.6% at a temperature setting of 32°C. When measuring using a Fluke INCUB II gold standard, the air flow parameter has the ability to measure values below 0.1 m/sec with an accuracy of 3 digits behind the comma. This study can be used as a reference by other researchers who want to develop an incubator analyzer in the

future. In addition, it is also recommended to use another type of airflow sensor which has higher sensitivity and accuracy than the D6F-V03A1. Furthermore, the development of this research can also add recordings that are connected to a computer to facilitate data processing.

## REFERENCES

- [1] L. Kristoffersen *et al.*, "Early skin-to-skin contact or incubator for very preterm infants: Study protocol for a randomized controlled trial," *Trials*, vol. 17, no. 1, pp. 1–9, 2016, doi: 10.1186/s13063-016-1730-5.
- [2] F. Althabe *et al.*, *Born Too Soon The Global Action Report on Preterm Birth*. 2012. doi: 10.1055/s-0031-1295659.
- [3] H. Mittal, L. Mathew, and A. Gupta, "Design and Development of an Infant Incubator for Controlling Multiple Parameters," *Int. J. Emerg. Trends Electr. Electron.*, vol. 11, no. 5, pp. 2320–9569, 2015.
- [4] R. Bahl, A. M. Gülmezoglu, A. Manu, M. Mathai, O. O. Were, and S. von Xylander, "WHO recommendations on interventions to improve preterm birth outcomes," in *World Health Organization*, 2015, pp. 1–98.
- [5] P. JMR, "Comparative Trial between Neonatal Intensive Care Incubator, Neonatal Laminar Flow Unit and Radiant Warmer," *Res. Pediatr. Neonatol.*, vol. 1, no. 1, 2017, doi: 10.31031/rpn.2017.01.000504.
- [6] J. M. R. Perez, S. G. Golombek, C. Fajardo, and A. Sola, "A laminar flow unit for the care of critically ill newborn infants," *Med. Devices Evid. Res.*, vol. 6, no. 1, pp. 163–167, 2013, doi: 10.2147/MDER.S51270.
- [7] V. Plangsangmas, S. Leeudomwong, and P. Kongthaworn, "Sound Pressure Level in an Infant Incubator," *Mapan - J. Metrol. Soc. India*, vol. 27, no. 4, pp. 199–203, 2012, doi: 10.1007/s12647-012-0030-0.
- [8] S. M. S. Cardoso, L. de C. Kozłowski, A. B. M. de Lacerda, J. M. Marques, and A. Ribas, "Newborn physiological responses to noise in the neonatal unit," *Braz. J. Otorhinolaryngol.*, vol. 81, no. 6, pp. 583–588, 2015, doi: 10.1016/j.bjorl.2014.11.008.
- [9] F. Fernández Zacarias, J. L. Beira Jiménez, P. J. Bustillo Velázquez-Gaztelu, R. Hernández Molina, and S. Lubián López, "Noise level in neonatal incubators: A comparative study of three models," *Int. J. Pediatr. Otorhinolaryngol.*, vol. 107, pp. 150–154, 2018, doi: 10.1016/j.ijporl.2018.02.013.
- [10] J. Neille, K. George, and K. Khoza-Shangase, "A study investigating sound sources and noise levels in neonatal intensive care units," *SAJCH South African J. Child Heal.*, vol. 8, no. 1, pp. 6–10, 2014, doi: 10.7196/SAJCH.676.
- [11] J. C. Fortes-Garrido, A. M. Velez-Pereira, M. Gázquez, M. Hidalgo-Hidalgo, and J. P. Bolívar, "The characterization of noise levels in a neonatal intensive care unit and the implications for noise management," *J. Environ. Heal. Sci. Eng.*, vol. 12, no. 1, pp. 1–8, 2014, doi: 10.1186/2052-336X-12-104.
- [12] A. Shimizu and H. Matsuo, "Sound Environments Surrounding Preterm Infants Within an Occupied Closed Incubator," *J. Pediatr. Nurs.*, vol. 31, no. 2, pp. e149–e154, 2016, doi: 10.1016/j.pedn.2015.10.011.
- [13] IEC 60601-2-19, *Medical electrical equipment - Part 2-19: Particular requirements for the basic safety and essential performance of infant incubators*. 2014.
- [14] J. M. de Araújo, J. M. P. de Menezes, A. A. M. de Albuquerque, O. da M. Almeida, and F. M. U. de Araújo, "Assessment and Certification of Neonatal Incubator Sensors through an Inferential Neural Network," *Sensors (Switzerland)*, vol. 13, no. 1, pp. 15613–15632, 2013, doi: 10.3390/s131115613.
- [15] A. Tavakoli Golpaygani, "Why should we have a periodic safety and performance program for medical devices," *J. Biomed. Phys. Eng.*, vol. 9, no. 2, pp. 251–256, 2019, doi: 10.31661/jbpe.v0i0.761.
- [16] S. Syaifudin, M. Ridha Mak'ruf, S. Luthfiyah, and S. Sumber, "Design of Two Channel Infusion Pump Analyzer Using Photo Diode Detector," *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 3, no. 2, pp. 65–69, 2021, doi: 10.35882/ijeemi.v3i2.5.
- [17] A. Zakia Febriyanti and P. Cahya Nugraha, "Temperature Calibrator Using Thermocouple Based on Microcontroller," *IJEEMI*, vol. 2, no. 1, pp. 13–20, 2020, doi: 10.35882/ijeemi.v2i1.3.
- [18] E. Özdemirci, M. Özarslan Yatak, F. Duran, and M. R. Canal, "Reliability assessments of infant incubator and the analyzer," *Gazi Univ. J. Sci.*, vol. 27, no. 4, pp. 1169–1175, 2014.
- [19] G. T. Sen and M. Yuksekkaya, "Desing and Test of an Incubator Analyzer," *ISMSIT 2018 - 2nd Int. Symp. Multidiscip. Stud. Innov. Technol. Proc.*, pp. 2–6, 2018, doi: 10.1109/ISMSIT.2018.8567049.
- [20] G. G. Subha and M. Fazilath, "INCUBATOR ANALYZER WITH AUTOMATIC SHUTTER OPENER," *Int. J. Adv. Inf. Eng. Technol.*, vol. 5, no. 5, pp. 15–18, 2018.
- [21] A. Rajalakshmi, K. A. Sunitha, and R. Venkataraman, "A survey on neonatal incubator monitoring system," *J. Phys. Conf. Ser.*, vol. 1362, no. 1, 2019, doi: 10.1088/1742-6596/1362/1/012128.
- [22] Laily Nurrohmah, Dwi Herry Andayani, and Andjar Pudji, "Development of Incubator Analyzer Using Personal Computer Equiped With Measurement Certificate," *J. Electron. Electromed. Eng. Med. Informatics*, vol. 2, no. 2, pp. 74–79, 2020, doi: 10.35882/ijeemi.v2i2.6.
- [23] I. K. N. Paramartha, T. Hamzah, B. Utomo, S. Luthfiyah, and E. ÖZDEMİRÇİ, "Lost Data and Transmition Speed Analysis on Incubator Analyzer Based IoT Technology," *Int. J. Adv. Heal. Sci. Technol.*, vol. 2, no. 1, pp. 39–46, 2022, doi: 10.35882/ijahst.v2i1.7.
- [24] V. N. Azkiyak, S. Syaifudin, and D. Titisari, "Incubator Analyzer Using Bluetooth Android Display (Humidity & Air Flow)," *Indones. J. Electron. Electromed. Eng. Med. informatics*, vol. 1, no. 2, pp. 71–77, 2020, doi: 10.35882/ijeemi.v1i2.5.
- [25] V. A. Athavale, A. Pati, A. K. M. B. Hossain, and S.



- Luthfiyah, "INCU Analyzer for Infant Incubator Based on Android Application Using Bluetooth Communication to Improve Calibration Monitoring," *J. Teknokes*, vol. 15, no. 1, pp. 1–8, 2022, doi: 10.35882/teknokes.v15i1.1.
- [26] P. Yin, M. Cao, and Y. Lin, "Research on flow sensor and the pressure sensor with digital asthma diagnosis technology," *Adv. Mater. Res.*, vol. 1014, pp. 110–114, 2014, doi: 10.4028/www.scientific.net/AMR.1014.110.
- [27] P. J. Webster, *Sleep Apnea Therapy Device*. Biomedical Engineering, 2017.
- [28] K. A. N. Guide, O. N. The, E. Of, and U. I. N. Measurement, *KAN GUIDE ON THE EVALUATION AND EXPRESSION OF*, no. 8. 2016.
- [29] R. A. Koestoer, I. Roihan, and A. D. Andrianto, "Product design, prototyping, and testing of twin incubator based on the concept of grashof incubator," *AIP Conf. Proc.*, vol. 2062, no. January, 2019, doi: 10.1063/1.5086560.
- [30] A. Alimuddin, A. Ria, S. Irma, A. Rocky, P. Hasudungan, and T. Taufik, "Development and Performance Study of Temperature and Hybrid Controller," *Mdpi*, vol. 14, no. 20, p. 6505, 2021.