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Development of Incubator Analyzer Using Personal Computer Equiped With Measurement Certificate

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Abstract

Baby incubators are used for premature babies when babies are born prematurely. In order to ensure the accuracy of medical devices, periodic tests and controls are needed, which aim to reduce the risk of measurement. The baby incubator can be tested with a calibration device that is used to calibrate temperature, noise, humidity, and airflow so that the conditions remain stable and within normal limits. The purpose of this study is to develop a calibrator device based on a computer to measure noise and airflow parameters. The standard incubator analyzer is not equipped with a computer interfacing. Furthermore, it needs data processing via Excel. Therefore, in this study, an incubator analyzer device is proposed, which has four parameters to measure, namely, temperature, noise, humidity, and airflow. The main part of this design is the Atmega328 Microcontroller, in which the function is used as a data processor, equipped with Bluetooth communication and data storage. Furthermore, the output will be displayed in a computer unit. In this study, the noise was measured using analog sound Sensor V2; and have the most significant error at 37oC setting temperature that is equal to 0.17%. At the same time, the airflow parameter measured using an airflow sensor, type D6F-V3A01. Based on the measurement, the error was 0.5% at a temperature setting of 36oC and 37oC. The use of displays on personal computers and data processing using Excel allows users to monitor calibration and data processing. The feasibility of this device is proven. Therefore, this design can be used for baby incubator calibration.

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I. INTRODUCTION

The baby incubator is a type of life support health equipment that serves to support the lives of patients who have failed in certain organs such as the heart and lungs, to monitor many vital functions of the baby's body such as heart rate, blood pressure, oxygen saturation and to support baby's breathing if needed. Some newborns who have a gestational age or too light birth weight will place the baby at a high risk of death [1]. In developing countries, 20 million premature babies or low birth weight babies die due to unreliable baby incubators, of which 4 million premature babies die in the first month [2]. Important parameters for baby incubators include temperature, relative humidity, noise, and airflow velocity. All four parameters must be within the measured standard. To see errors in the baby incubator device can be measured or confirmed with a baby incubator calibration device. The baby incubator calibration device, the incubator analyzer, can help determine whether a baby incubator is eligible or not [3]. To ensure the accuracy of medical devices, periodic tests and controls need to be carried out, aimed at reducing the risk or preventing inaccurate or inaccurate measurements [4]. If the noise and airflow parameters of the baby incubator are made inadequate or inaccurate measurements, it can threaten the baby's safety.

Emre Ozdemđ, et al [4] once analyzed the "Reliability Assessments of Infant Incubators and the Analyzer" states that if a baby incubator exceeds the normal limits agreed upon, it will harm the baby, for example, if the airflow exceeds the normal limit will Asphyxia occurs in infants, and if the noise exceeds the normal limit there will be dizziness, increased blood pressure, and decreased fluid in the baby's brain [3] In 2018, G.Gnancy Subha and M.Fazilath made an incubator analyzer using sensors to detect the presence of toxic gas in baby incubators. The study stated that the parameters of temperature, humidity, noise, and airflow in the baby incubator must be at the limit that refers to ANSI / AAMI. If it exceeds the rule limit (for example airflow <0.4m / s), it will have an impact on the health and safety of infants [5]. In 2019 the device was developed by Niki Putri by displaying measurement results through Delphi and SD Card storage. According to the author, the module is less effective because if the data is stored in the SD Card if the calibration officer will display the measurement results must first take the SD Card and put it on a personal computer.

Seeing this weakness, the researchers made a device incubator analyzer based on the computer by adding data processing in Microsoft Excel so that the operator or calibration officer did not process the measurement results manually and display on a personal computer that is on Delphi.

The composition of this article consists of five section, Section I presented the introduction of this study, section II described the materials and methods, section III explained the Result of the experiment, section IV discussed the result, and section V is the conclusion.

II. Materials and methods

A. Theory

Incubator Analyzer is a device designed to verify the work system and environmental conditions in the Baby Incubator device. This calibration device can detect several parameters such as airflow, noise, temperature, and relative humidity [3] The standards required for a Baby Incubator device to be operated and used on patients can be seen at AAMI (Advancing Safety in Health Technology) consisting of more than 100 technical committees and working groups that produce recommended practice standards and reports on technical information for medical devices. Recommended standards and practices represent national consensus and many have been approved by the American National Standards Institute (ANSI) as American National Standards. AAMI also manages several international technical committees from the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC), and the US Technical Advisory Group (TAG).

Every parameter on the baby incubator must enter within the range specified in one of the standards above. One of the standards that will be explained below is SNI IEC 60601-2-19: 2014, the purpose of this special standard is to establish special basic safety requirements and essential performance for infant incubators that can minimize harm to patients and operators and determine tests that are compatible with requirements can be verified. The range of conditions needed so that an infant incubator can be used are as follows:

a. Temperature

Temperature regulation is the most important factor affecting the premature baby [24] Average incubator temperatures can be taken at regular intervals obtained during stable temperature conditions. During an hour the temperature of the incubator should not change more than 1 ° C. Compliance is checked by measuring at a controlled temperature of 32 ° C and 36 ° C in at least 1 hour [8]

b. Humidity

Babies treated in incubators with a relative humidity of 30%-60% have a higher mortality rate than babies treated at a relative humidity of 80%-90%. [25] Referring to SNI IEC 60601-2-19: 2014, each relative humidity value shown must have an accuracy of +10% against the actual measured value. [8]

c. Airflow velocity (m / s)

Measurement of airflow is a measurement needed in various fields such as medical instrumentation, process control, environmental monitoring, and so on [22] Airflow or air circulation rate is very calculated in the baby incubator because it can affect the health of the baby. In normal use, the airspeed should not be more than 0.35 m/s. The limit of 0.35 m/s is taken from measurements on units which in this case are deemed to have met the requirements [8] To detect airflow in a baby incubator using a sensor from OMRON with type D6F-V30A1 which is designed to measure air velocity and has a flow range of 0 to 3 m/s, by having Micro Electromechanical Systems (MEMS) technology the sensor can detect flow rates and flow directions [20] [21] In 2012 there was a study using the D6F-V03A1 sensor which measures the airflow of the Air Conditioner. It was explained that sensors near the AC showed an increase in airflow velocity greater than sensors that were far from the AC [23]

d. Noise

Noise is an unwanted sound from a business or activity at a certain level and time that can cause human health problems and environmental comfort that are spatially and temporally spread [8] [9] [15] or all unwanted sounds that originate from the devices - production process equipment and/or work devices at a certain level can cause hearing loss [10]. Spatial and temporal distribution are related [16]. Spatial is the spread related to space, while temporal is the spread associated with the cycle of time. [17] To detect noise in a baby incubator using Analog Sound Sensor V2. The output of this sensor is analog, so it must be treated with a signal conditioning circuit. Signal conditioners that can be used to handle small signals are signal conditioners with a gain method so that the output can be processed with electrical circuits or digital systems [18] [19].

1. Baby Incubator

Baby Incubator is a device used to warm newborns and is often used on babies born prematurely. This baby incubator also serves to maintain the warmth, the humidity of the baby's body and can prevent respiratory infections in infants and to isolate newborns, especially babies born prematurely [6].

2. Calibration

According to ISO / IEC Guide 17025: 2005 and Vocabulary of International Metrology (VIM), calibration is an activity to determine the conventional correctness of the value of measuring instruments and measuring materials by comparing them against traceable standards to national and international standards for units international and/or certified standards and reference materials [7].

3. Delphi

Delphi is an application to provide database connectivity for programmers [11]. Delphi's strengths are ease of preparation of the User Interface, Object Pascal Language, and Native Code [12].

4. Microsoft Excel

Microsoft Excel is a data processing software from Microsoft in the form of spreadsheets. In Excel, there is a workbook [13]. Inside the workbook there is a worksheet that is used to process data [14]. In processing the measurement results there are several sheets such as worksheets, data analysis, interpolation, uncertainty analysis, supervisors, customers, and safety tests.

5. Uncertainty

There are several types of uncertainty, i.e.:

a. Uncertainty Type A (UA) is a source of uncertainty derived from a determination by statistical methods. The formula for uncertainty is as follows:

$$UA = \frac{SD}{\sqrt{n}} \quad (1)$$

Note: SD: Standard Deviation
n: A lot of data

b. Type B (UB) uncertainty is a source of uncertainty derived from scientific information such as device calibration certificates or scientific journals. The formula for uncertainty is as follows:

$$UB = \frac{Uncertainty\ of\ information}{k} \quad (2)$$

Note: k: Coverage Factor is worth 2

c. Combined uncertainty (UC) is a combination of uncertainty in both type A and type B.

$$UC = \sqrt{UA^2 + UB^2} \quad (3)$$

d. The uncertainty of the stretch is the magnitude that defines the interval around the expected measurement results including most of the distribution of values that can be given on the measuring scale. Whereas the coverage factor contained in the calculation of type B uncertainty is the numerical factor used as a multiplier of the combined standard uncertainty to obtain the uncertainty of the stretch (U95).

$$U95 = | k | \times UC \quad (4)$$

Note:
UC: Combined uncertainty Type A and Type B

B. *Experimental Setup*

This research uses baby incubator objects and Fluke Biomedical Brand II Incubator Analyzer. Data collection is done sequentially starting from the temperature 34⁰C, 36⁰C, and 37⁰C and carried out every 10 minutes as much as 6 times.

C. *Materials and Device*

This study uses a sensor Analog Sound Sensor V2 for noise parameter and Airflow sensor from OMRON type D6F-V30A1 for the airflow parameter. Components used as a sensor microcontroller Arduino Uno, HC-05 for Bluetooth module, LCD, and Personal Computer as a display.

D. *Experiment*

In this study, the researchers measured the noise and airflow in the baby incubator with the temperature setting 34⁰C, 36⁰C, and 37⁰C. This measurement takes 60 minutes every temperature setting. After that Bluetooth HC-05 in module sends data to the personal computer and shows at Delphi. Then all data be processed in Excel to determine the baby incubator eligibility on the certificate. Measurement of this module using the Fluke Biomedical Brand II Incubator Analyzer for comparison. This research was conducted in Direktorat Poltekkes Surabaya.

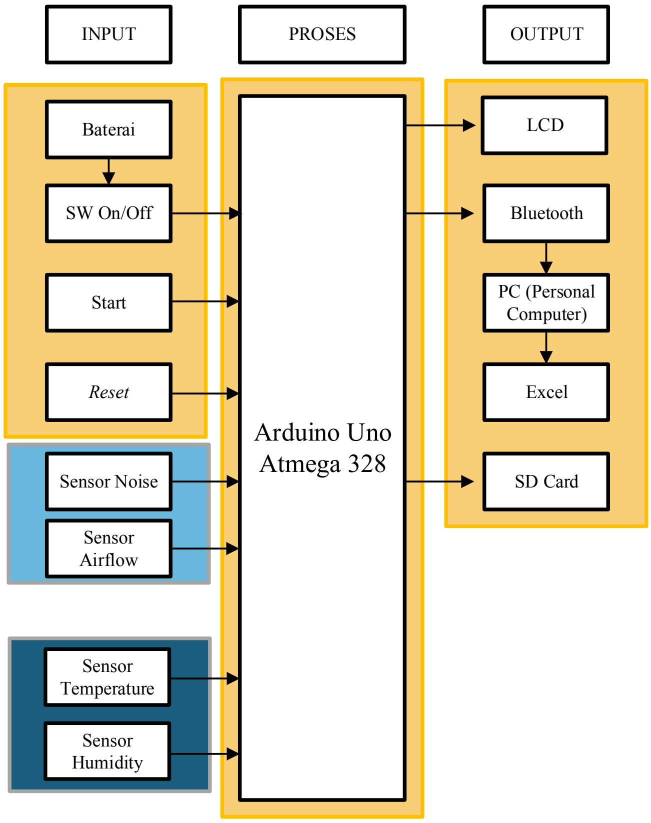

Fig. 1. Block diagram of Incubator Analyzer

E. *The Block Diagram*

When the on / off button is pressed, all circuits get voltage including all sensors, so that the sensor is ready and ready to use. Then when the start button is pressed, the noise sensor and airflow sensor will start operating detecting noise and airflow velocity around the closed hood of the baby incubator. The sensor readings will be processed into Arduino Uno AT Mega 328 and then displayed on the LCD and displayed on a PC (Personal Computer) sent via Bluetooth. Data from the measurement/reading of the two sensors will be processed by excel automatically which will be generated a calibration

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certificate. After the process is complete, the reset button can be pressed to start the measurement (reading) of other baby incubator devices (**Fig. 1**).

F. The Flowchart

Arduino program runs like a flowchart shown in **Fig. 2**. When the start button is pressed, the noise sensor and airflow sensor will operate to read the noise and airflow inside the baby incubator. After that, the measurement results will be sent via Bluetooth (transmitter) which will be received by the receiver, namely PC (Personal Computer). Then the data will be processed automatically using Excel. The reset button is used if the user (calibration officer) wants to calibrate again.

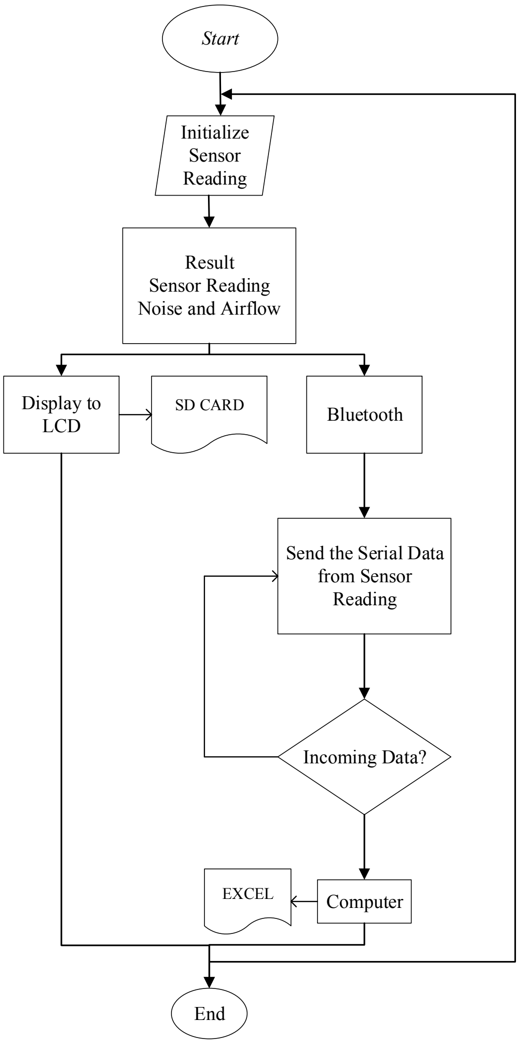

Fig. 2. Flowchart Program Arduino

G. Circuit

1) Non-Inverting Amplifier

The below network is a non-inverting network that acts as an amplifier for low-voltage noise sensor output voltage. The non-inverting network is the connection between the noise sensor and the Arduino on port A0 where the noise measurement inside the baby incubator uses the Analog Sound Sensor V2 sensor (**Fig. 3**).

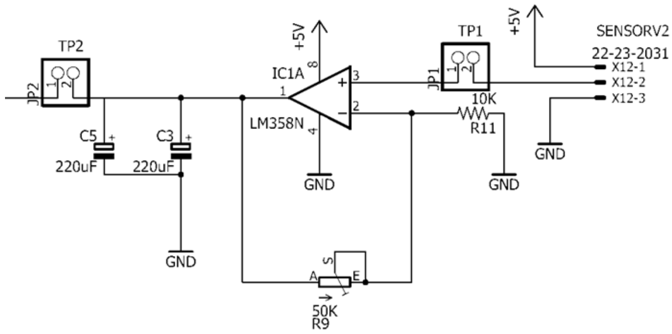

Fig. 3. Non-Inverting Amplifier

2) Airflow Circuit

Airflow sensors from OMRON with type D6F-V30A1 is connected to the Arduino Microcontroller circuit by connecting the sensor pin 2 outputs to analog Arduino pin (**Fig. 4**).

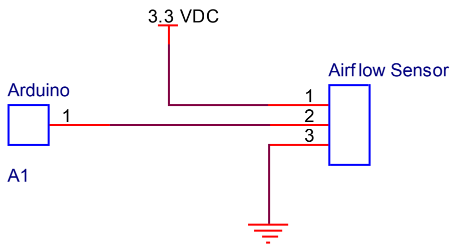

Fig. 4. Airflow Circuit

III. RESULT

Below are the results of the research conducted by researchers.

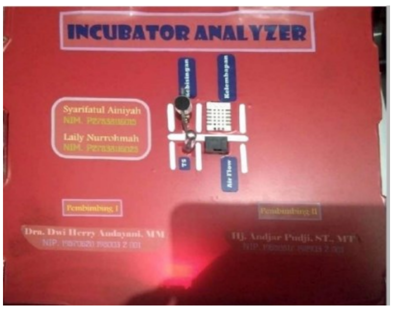

Fig. 5. Incubator Analyzer Module

1) Incubator Analyzer Design

Image design devices can be seen in **Fig. 5** and **Fig. 6**. There are 4 parameters in the incubator analyzer module namely temperature, humidity, noise, and airflow. The focus of this research is noise and airflow. The results of measurements from the module are displayed via LCD. there is a save button to save data on the SD card and a reset button to repeat the baby incubator measurements from the start.

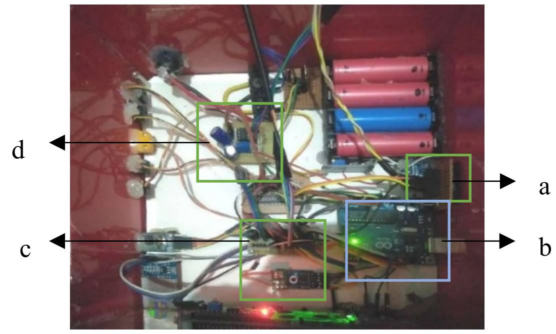

Fig. 6. Incubator Analyzer Circuit

Note:

a. Airflow Sensor Circuit
b. Arduino Uno
c. Temperature Sensor Circuit
d. Noise Sensor Circuit

2) Personal Computer Display by Delphi

Button description on the Delphi display (**Fig. 7** and **Fig. 8**) :

a. The Setting is to fill com manually in the settings button according to the Bluetooth serial port.
b. The Start is to show in Delphi all parameter values in Delphi.
c. The Stop is to stop all the programs in the Delphi display.
d. The Reset is to resets all data in the Delphi display.
e. Excel is to open Microsoft Excel.
f. Save is to open workbooks in Microsoft Excel with the name "bismillah" on Local Disk D.

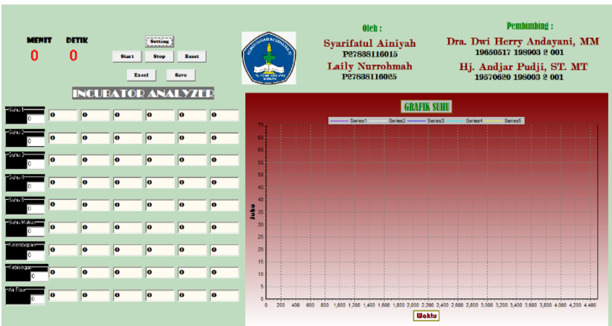

Fig. 7. Delphi Display

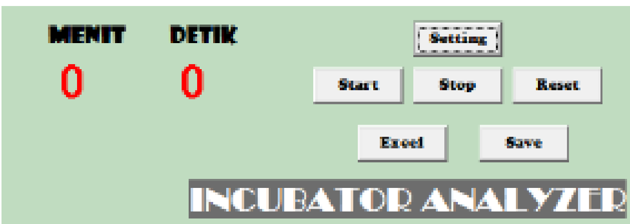

Fig. 8. The button of Delphi Display

3) Incubator Analyzer Using Program Arduino

The Arduino program is divided into 2 namely the noise and airflow reading program and the data delivery program to Delphi.

Pseudo Code: Sensor Reading Program

```
INIT:
 int bising;float x; float db; float airflow; float ms; float
 data7; float data9;
 int datakirim1, datakirim2, datakirim3, datakirim4,
 datakirim5, datakirim6, datakirim7, datakirim8
 datakirim9;
LOOP:
 int bising = analogRead(A0);
 x=bising*3.3/1023;
 IF (x>=0.02&&x<0.03) THEN
  db = ((200 * x) + 36);
 ENDIF
 float data7a = db;
 data7a= db;
 lcd.setCursor(0, 1);
 PRINT db

 float airflow = analogRead(A1);
 x = airflow*3.3/1023;
 ms = (0.100*x) + 0.1;
 data9 = ms;
 float data9a=ms;
 lcd.setCursor(0, 4);
 PRINT airflow
 PRINT
ENDLOOP
```

The program above is a program for reading noise sensors and airflow sensors.

Pseudo Code:. Sending data to Delphi.

```
LOOP:
 PRINTSERIAL "a"
 adc1=datakirim7/100;
 adc2=datakirim7%100;
 PRINTSERIAL adc1
 PRINTSERIAL adc2
 adc1=datakirim9/100;
 adc2=datakirim9%100;
 PRINTSERIAL adc1
 PRINTSERIAL adc2
 PRINTSERIAL "b"
ENDLOOP
```

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The above program is to display the value of each sensor on the serial monitor that functions for sending data to Delphi. At each sensor initialization given an alphabetical code, this code is then used to initialize the Delphi application and the Delphi application must use the same alphabetical code so that the value of each sensor can be displayed on the Delphi display.

4) Incubator Analyzer Using Delphi Programming

Pseudo Code:. Saving data in Excel

```
DO:
  Ex:=CreateOleObject('Excel.Application');
  Ex.Workbooks.Open ('D:\bismillah.xls');
  Ex.Visible:=true;
END;
```

The program above is a program for storing measurement data from a module into Microsoft Excel which already contains a certificate format that is saved with the file name "file1.txt" on Local Disk D.

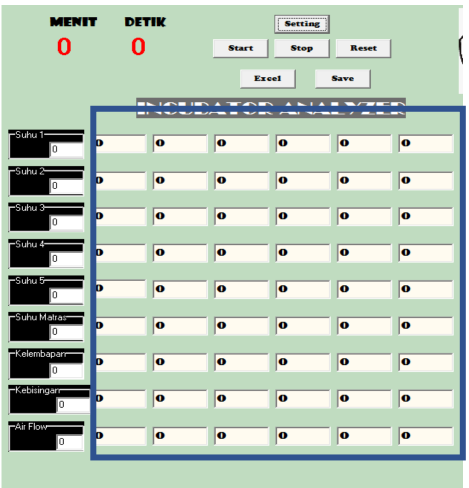
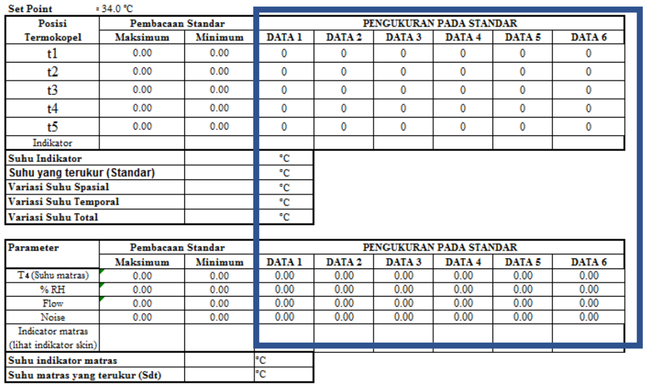


Fig. 9. Delphi Display

5) Data from Delphi to Excel

Baby incubator measurements that have been made and performed at Delphi will then be processed or counted into certificates to determine the appropriateness of the calibrated device. In Delphi display there are columns to display the measurement results of the incubator analyzer module. When the measurement has been completed, the user presses the Save button on the Delphi display to open a certificate format in Excel that has been created and is on Local Disk D with the file name "bismillah". After opening the user presses the Excel button to copy data from Delphi into the certificate (**Fig. 9**).

Data from these columns will be copied and entered into an excel file that already has a certificate format. As follows (**Fig. 10**)



Set Point = 34.0 °C

Posisi Termokopel	Pembacaan Standar		PENGUKURAN PADA STANDAR					
	Maksimum	Minimum	DATA 1	DATA 2	DATA 3	DATA 4	DATA 5	DATA 6
t1	0.00	0.00	0	0	0	0	0	0
t2	0.00	0.00	0	0	0	0	0	0
t3	0.00	0.00	0	0	0	0	0	0
t4	0.00	0.00	0	0	0	0	0	0
t5	0.00	0.00	0	0	0	0	0	0
Indikator								

Suhu Indikator		°C
Suhu yang terukur (Standar)		°C
Variasi Suhu Spasial		°C
Variasi Suhu Temporal		°C
Variasi Suhu Total		°C

Parameter	Pembacaan Standar		PENGUKURAN PADA STANDAR					
	Maksimum	Minimum	DATA 1	DATA 2	DATA 3	DATA 4	DATA 5	DATA 6
T_4 (Suhu matras)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
% RH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Noise	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indicator matras (lihat indikator skin)								

Suhu indikator matras		°C
Suhu matras yang terukur (Sdt)		°C

Fig. 10. An example of measurement certificate in Bahasa

After all files are copied, the data will be calculated or processed in the certificate to determine the eligibility of the calibrated baby incubator.

6) The Error Measurement

The chart above explains the noise error between the measurement results of the module and the standard device (**Fig. 11** and **Fig. 12**). When the temperature 34°C and 36°C error is 0.13%, the temperature 37°C error is 0.17%.

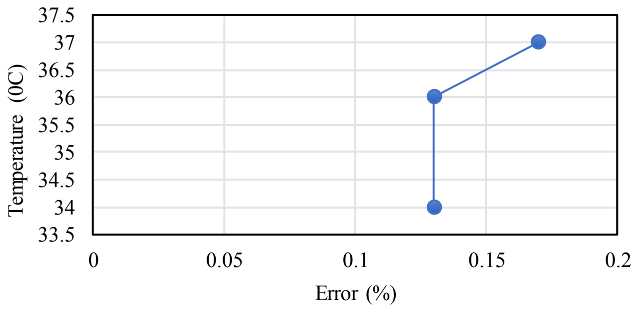


Fig. 11. Noise error between design and incu II (calibrator)

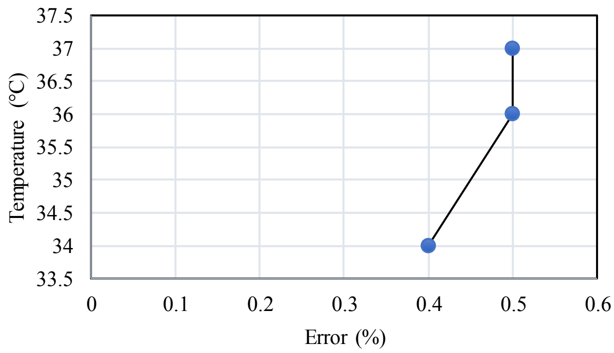


Fig. 12. Airflow error between module and incu II

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The chart above explains the airflow error between the measurement results of the module and the standard device. When the temperature 34°C error is 0.4%, the temperature 36°C and 37°C error is 0.5%.

7) The Result of the Certificate

Below is the result of the comparison of certificates from INCU II devices and the incubator analyzer module (**Fig. 13** and **Fig. 14**):

a. Temperature Setting 34 ^{0}C

II. Hasil Pengukuran Kinerja

Set Point (°C)	Penunjukan Indikator (°C)	Hasil Ukur Standar (°C)	Kesalahan	Variasi suhu Spasial (°C)	Variasi suhu Temporal (°C)	Variasi suhu Total (°C)	Ketidakpastian Pengukuran (U_{95})
34	0.0	0.00	0.00	2.93	1.36	3.58	± 5.652

Set Point (°C)	Parameter	Hasil Ukur Standar	Koreksi	Ketidakpastian Pengukuran
34	*Suhu Matras (°C)*	0.00	34.00	± 0.09

Set Point (°C)	Parameter	Hasil Ukur Standar	Kesalahan Maks. Yang Diijinkan	Ketidakpastian Pengukuran
34	[illegible]	[illegible]	[illegible]	[illegible]
	Air Flow (m/s)	0.15	≤ 0.35 M/S	± 0.01
	Noise (dBA)	59.75	< 60 dBA	± 0.43

Modul

Fig. 13. An example of measurement certificate in Bahasa

The results of the certificate on the baby incubator calibration that uses the module states that the baby incubator is not suitable for use because there are parameters that exceed the maximum allowable error.

Hasil Pengukuran Kinerja

Set Point (°C)	Penunjukan Indikator (°C)	Hasil Ukur Standar (°C)	Kesalahan	Variasi suhu Spasial (°C)	Variasi suhu Temporal (°C)	Variasi suhu Total (°C)	Ketidakpastian Pengukuran (U_{95})
34	0.0	0.00	0.00	1.36	1.06	1.24	± 3.106

Set Point (°C)	Parameter	Hasil Ukur Standar	Koreksi	Ketidakpastian Pengukuran
34	*Suhu Matras (°C)*	0.00	34.00	± 0.05

Set Point (°C)	Parameter	Hasil Ukur Standar	Kesalahan Maks. Yang Diijinkan	Ketidakpastian Pengukuran
34	*%RH*	33.43	> 70%	± 33.18
	Air Flow (m/s)	0.10	≤ 0.35 M/S	± 0.00
	Noise (dBA)	52.85	< 60 dBA	± 3.64

Alat Standar

Fig. 14. An example of measurement certificate in Bahasa

The results of the certificate on the baby incubator calibration that uses INCU II (standard equipment) states that the baby incubator is suitable for use (**Fig. 15** and **Fig. 16**).

b. Temperature Setting 36 ^{0}C

III. Hasil Pengukuran Kinerja

Set Point (°C)	Penunjukan Indikator (°C)	Hasil Ukur Standar (°C)	Kesalahan	Variasi suhu Spasial (°C)	Variasi suhu Temporal (°C)	Variasi suhu Total (°C)	Ketidakpastian Pengukuran (U_{95})
36	0.0	0.00	0.00	3.02	0.46	3.20	± 5.351

Set Point (°C)	Parameter	Hasil Ukur Standar	Koreksi	Ketidakpastian Pengukuran
36	*Suhu Matras (°C)*	0.00	36.00	± 0.72

Set Point (°C)	Parameter	Hasil Ukur Standar	Kesalahan Maks. Yang Diijinkan	Ketidakpastian Pengukuran
36	*%RH*	45.40	> 70%	± 2.77
	Air Flow (m/s)	0.15	≤ 0.35 M/S	± 0.01
	Noise (dBA)	60.34	< 60 dBA	± 0.25

Modul

Fig. 15. An example of measurement certificate in Bahasa

The results of the certificate on the baby incubator calibration that uses the module states that the baby incubator is not suitable for use because there are parameters that exceed the maximum allowable error.

III. Hasil Pengukuran Kinerja

Set Point (°C)	Penunjukan Indikator (°C)	Hasil Ukur Standar (°C)	Kesalahan	Variasi suhu Spasial (°C)	Variasi suhu Temporal (°C)	Variasi suhu Total (°C)	Ketidakpastian Pengukuran (U_{95})
36	0.0	0.00	0.00	0.90	0.97	1.37	± 2.440

Set Point (°C)	Parameter	Hasil Ukur Standar	Koreksi	Ketidakpastian Pengukuran
36	*Suhu Matras (°C)*	0.00	36.00	± 0.06

Set Point (°C)	Parameter	Hasil Ukur Standar	Kesalahan Maks. Yang Diijinkan	Ketidakpastian Pengukuran
36	*%RH*	[illegible]	> 70%	[illegible]
	Air Flow (m/s)	0.10	≤ 0.35 M/S	± 0.00
	Noise (dBA)	52.95	< 60 dBA	± 2.94

Alat Standar

Fig. 16. An example of measurement certificate in Bahasa

The results of the certificate on the baby incubator calibration that uses INCU II (standard equipment) states that the baby incubator is suitable for use.

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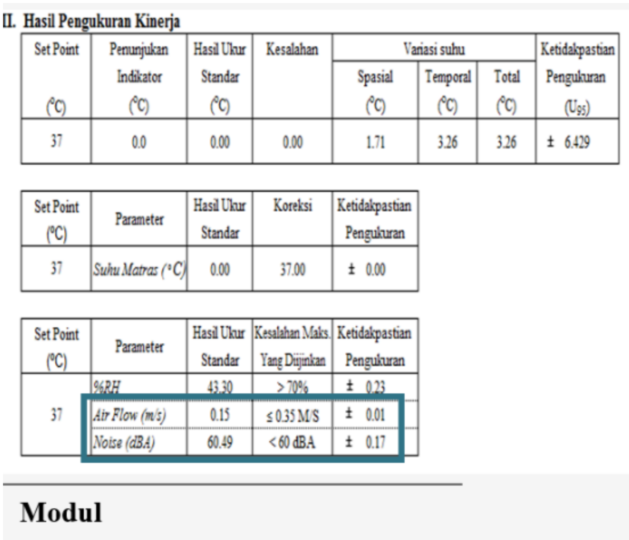
c. Temperature Setting 37 ^{0}C

The results of the certificate on the baby incubator calibration that uses the module states that the baby incubator is not suitable for use because there are parameters that exceed the maximum allowable error (**Fig. 17** and **Fig. 18**).



II. Hasil Pengukuran Kinerja

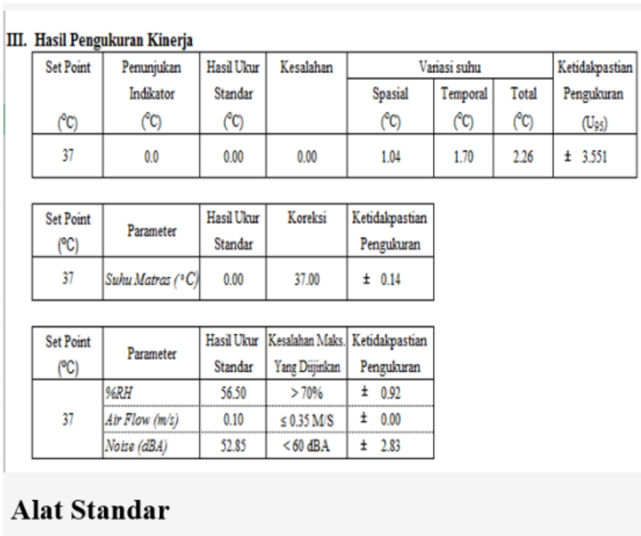
Set Point (°C)	Penunjukan Indikator (°C)	Hasil Ukur Standar (°C)	Kesalahan	Variasi suhu Spasial (°C)	Variasi suhu Temporal (°C)	Variasi suhu Total (°C)	Ketidakpastian Pengukuran (U_{95})
37	0.0	0.00	0.00	1.71	3.26	3.26	± 6.429

Set Point (°C)	Parameter	Hasil Ukur Standar	Koreksi	Ketidakpastian Pengukuran
37	*Suhu Matras (°C)*	0.00	37.00	± 0.00

Set Point (°C)	Parameter	Hasil Ukur Standar	Kesalahan Maks. Yang Diijinkan	Ketidakpastian Pengukuran
37	*%RH*	43.30	> 70%	± 0.23
	Air Flow (m/s)	0.15	≤ 0.35 M/S	± 0.01
	Noise (dBA)	60.49	< 60 dBA	± 0.17

Modul

Fig. 17. An example of measurement certificate in Bahasa



III. Hasil Pengukuran Kinerja

Set Point (°C)	Penunjukan Indikator (°C)	Hasil Ukur Standar (°C)	Kesalahan	Variasi suhu Spasial (°C)	Variasi suhu Temporal (°C)	Variasi suhu Total (°C)	Ketidakpastian Pengukuran (U_{95})
37	0.0	0.00	0.00	1.04	1.70	2.26	± 3.551

Set Point (°C)	Parameter	Hasil Ukur Standar	Koreksi	Ketidakpastian Pengukuran
37	*Suhu Matras (°C)*	0.00	37.00	± 0.14

Set Point (°C)	Parameter	Hasil Ukur Standar	Kesalahan Maks. Yang Diijinkan	Ketidakpastian Pengukuran
37	*%RH*	56.50	> 70%	± 0.92
	Air Flow (m/s)	0.10	≤ 0.35 M/S	± 0.00
	Noise (dBA)	52.85	< 60 dBA	± 2.83

Alat Standar

Fig. 18. An example of measurement certificate in Bahasa

The results of the certificate on the baby incubator calibration that uses INCU II (standard equipment) states that the baby incubator is suitable for use.

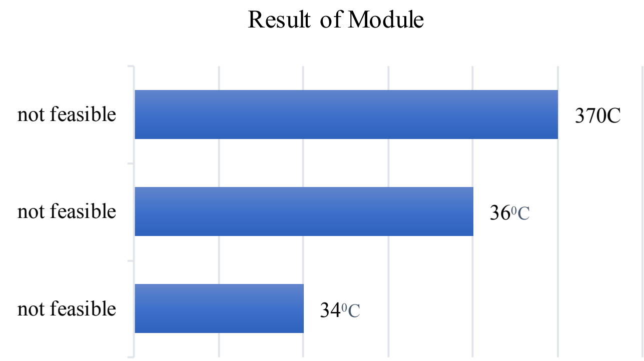


Fig. 19. Comparison of certificate results between design and incu II (calibrator)

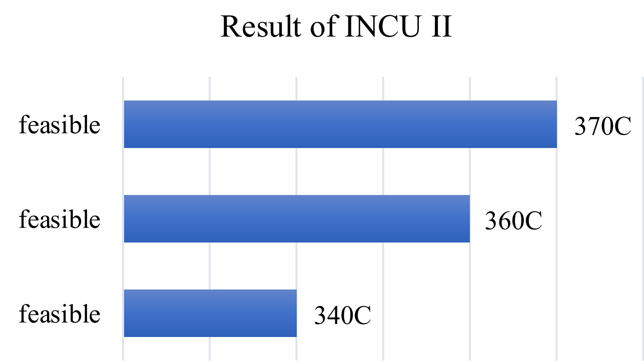


Fig. 20. Comparison of certificate results between design and incu II (calibrator)

The diagram states that if the calibration results from the module at all setting temperatures are 34^{0}C, 36^{0}C, and 37^{0}C states that the baby incubator is not suitable for use, while the calibration results from INCU II at all temperature settings indicate the baby incubator is suitable for use (**Fig. 19** and **Fig. 20**).

IV. Discussion

This study states that the measurement process using the module incubator analyzer can be seen or observed through a personal computer and the measurement results will be processed into Microsoft Excel to determine the eligibility of the baby incubator device. This can make it easier for users to more effectively and quickly find out the results of the calibration. Whereas in previous studies, the module incubator analyzer has not used processing through Microsoft Excel.

Then based on measurements made by comparing the results between the module and INCU II with a time of 60 minutes for each temperature setting and making 6 measurements, then the error value of each parameter will be obtained. The biggest error in noise parameters lies in the temperature regulation of 37^{0}C and the biggest error in the regulation of airflow parameters is 36^{0}C and 37^{0}C.

V. CONCLUSION

The airflow sensor module has the highest error at 36^0C and 37^0C that is equal to 0.5%, and the highest error of noise sensor module is 0.17% at 37°C setting temperature, this can be influenced by operator reading errors and noise conditions around the baby incubator. Using data transmission with Bluetooth HC-05 displayed on a Personal Computer (PC) via Delphi as well as processing certificates through Excel. The measurement results displayed on Delphi will be stored in the certificate processing sheet which will facilitate the user to do data processing. There are differences in the results of certificates in the Incubator Analyzer and INCU II modules.

REFERENCE

[1] 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.

[2] M. Shaib, M. Rashid, L. Hamawy, M. Arnout, I. El Majzoub, and A. J. Zaylaa, "Advanced portable preterm baby incubator," *Int. Conf. Adv. Biomed. Eng. ICABME*, vol. 2017-Octob, pp. 1–4, 2017.

[3] E. Ozdemİrcİ, 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.

[4] G. T. Sen and M. Yuksekkaya, "Desing and Test of an Incubator Analyzer," in *ISMSIT 2018 - 2nd International Symposium on Multidisciplinary Studies and Innovative Technologies, Proceedings*, 2018.

[5] M. F. G.Gnancy Subha, "Incubator-Analayzer-With-Automatic-Shutter-Opener," *Int. J. Adv. Inf. Eng. Technol.*, vol. 5, pp. 15–18, 2018.

[6] A. S. Utomo, A. B. Satrya, and Y. Tapparan, "Monitoring Baby Incubator Sentral Dengan Komunikasi Wireless," *Simetris J. Tek. Mesin, Elektro dan Ilmu Komput.*, vol. 9, no. 1, pp. 225–230, 2018.

[7] O. M. Vasilevskyi, "Calibration method to assess the accuracy of measurement devices using the theory of uncertainty," *Int. J. Metrol. Qual. Eng.*, vol. 5, no. 4, p. 403, 2014.

[8] ANSI/AAMI/IEC, "Medical electrical equipment — Part 2-4 : Particular requirements for basic safety and essential performance of cardiac defibrillators Objectives and uses of AAMI standards and recommended practices," *Med. Instrum.*, 2011.

[9] Keputusan, M. N. L. Hidup, And N. : Kep-48/Menlh/11/1996, "Keputusan Menteri Negara Lingkungan Hidup," pp. 1–7, 1996.

[10] Menteri Tenaga Kerja Kep .51/Men/1999, "Keputusan Menteri Tenaga Kerja Republik Indonesia No.51 Tentang Nilai Ambang Batas Faktor Fisika di Tempat Kerja," *Kep .51/Men/1999*, pp. 1–9, 1999.

[11] C. Vogel, S. Zwolinsky, C. Griffiths, M. Hobbs, E. Henderson, and E. Wilkins, "A Delphi study to build consensus on the definition and use of big data in obesity research," *Int. J. Obes.*, vol. 43, no. 12, pp. 2573–2586, 2019.

[12] E. J. Billo, *Excel Formulas and Functions*. 2011.

[13] Kusnassriyanto, *Belajar Pemrograman Delphi*, 1st ed. Bandung: Modula Bandung, 2011.

[14] A. Stevens, *C programming*, vol. 27, no. 12. 2002.

[15] L. Hallett, M. Tatum, G. Thomas, S. Sousan, K. Koehler, and T. Peters, "An inexpensive sensor for noise," *J. Occup. Environ. Hyg.*, vol. 15, no. 5, pp. 448–454, 2018.

[16] J. Holland, T. Gordon, and E. Lahelma, "Temporal, spatial and embodied relations in the teacher's day at school," *Ethnogr. Educ.*, vol. 2, no. 2, pp. 221–237, 2007.

[17] B. Setioko, "Transformasi Ruang Perkotaan di Permukiman Nelayan (Studi Kasus: Tambakmulyo, Semarang)," *J. Tataloka*, vol. 15, no. 3, p. 192, 2013.

[18] M. T. Iwan Setiawan, S.T., "Sensor dan Tranduser," *Semarang*, pp. 1–49, 2011.

[19] A. H. Novianto, "Pengkondisi Sinyal Dan Akuisisi Data Sensor Tekanan :," 2016.

[20] M. Flow-sensor, "D6F-V03A1 The unique dust separating structure ," pp. 3–6.

[21] H. Lim, F. Xue, S. Liu, S. Pan, J. Miao, and L. K. Norford, "Demonstration Abstract: A MEMS-based Air Flow Sensor Network," vol. 0, pp. 321–322, 2014.

[22] Y. H. Wang, C. Y. Lee, and C. M. Chiang, "A MEMS-based air flow sensor with a free-standing microcantilever structure," *Sensors*, vol. 7, no. 10, pp. 2389–2401, 2007.

[23] S. Ueki, H. Imamoto, K. Ando, T. Fujimori, and S. Sugiyama, "Development of Multi-functional Sensor Module for Energy Saving Air Conditioner System," 2012.

[24] M. Koli, P. Ladge, B. Prasad, R. Boria, and N. J. Balur, "Intelligent Baby Incubator," *Proc. 2nd Int. Conf. Electron. Commun. Aerosp. Technol. ICECA 2018*, no. Iceca, pp. 1036–1042, 2018.

[25] L. Glass and L. Glass, "Preterm Infant Incubator Humidity Levels : A Systematic Review Walden University This is to certify that the doctoral study by," 2019.