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Analysis of Abdominal Respiratory Sensor Performance in Sleep Apnea Conditions

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ABSTRACT Abdominal respiratory sensor is a sensor used to detect sleep apnea that is specifically for neonates, this sensor is specifically for neonates because the use of this sensor does not require a voltage input to activate the sensor. In the absence of voltage input so as not to disturb the heart rhythm in neonates. When the sensor is no longer elastic, the pressure difference generated by the sensor will be unstable so that the sensor cannot work optimally. With these conditions, the period of use of the sensor needs to be known how durable the sensor is when it is used on patients so that the sensor can maximally detect the occurrence of apnea in neonates. How many times have you been in apnea. This study uses an Arduino microcontroller to process the pressure value and RR value generated by the stomach sensor and the MPX5010dp pressure sensor. the research method used is to use a simulator to analyze the combination of abdominal sensors and pressure sensors to monitor apnea. If viewed based on the average error, the error value in the RR 10bpm setting is ±0.185%, the RR 15 setting is ±0.245%, and the setting RR 20bpm is ±0.383%. From the average error value, it can be said that the higher the RR setting value, the higher the average error for each decrease in pressure output. it can be concluded that the performance of the use of the Abdominal Respiratory Sensor and Pressure Sensor on the Apnea Monitoring module functions well in detecting RR according to the settings on the simulator for 3-day monitoring. The development that can be done in this research is to use a more sensitive pressure sensor so that the results obtained are more stable and make the module display more attractive.

INDEX TERMS Abdominal Respiratory Sensor, MPX5700, Apnea

I. INTRODUCTION

Sleep apnea (SA) is one of the most common forms of breathing disorders that occur during sleep[1][2], [3]. Sleep apnea is characterized by the cessation of air flow to the lungs, where when breathing stops for more than 10 seconds, this event is said to be apnea[1]. When sleep apnea occurs or stops breathing, there will be a decrease in oxyhemoglobin saturation of more than 3% or it ends with awakening from sleep. Sleep apnea has a serious impact on patients, especially it can cause heart problems (hypertension, coronary artery disease, and arrhythmias). In addition, disruption of the sleep cycle can also have a negative impact on quality of life. This often causes depression, daytime fatigue and sleepiness. Sleep apnea events are divided into 3 classes, namely: obstructive sleep apnea (OSA), central sleep apnea (CSA), and mixed sleep apnea (MSA) [3], [4].

In 2016 Ifana Mahbub, et al made A Low Power Wireless Breathing Monitoring System Using Piezoelectric Transducer. This tool uses a piezoelectric sensor to monitor breathing which is then sent wirelessly. However, the delivery system is not explained. Then in 2018 a tool, Measurement of Respiratory Rate Using Piezoelectric Sensor was made, by Shankar N, et al. This device uses piezoelectricity to detect breathing which is placed on the patient's chest. However, this tool still uses a USB serial RS232[5] in the system for sending the respiratory value which is then displayed on a PC.

The apnea monitor tool uses piezoelectric sensors that have been made, among others in 2017 by Yin Yan Lin, et al with the title Sleep Apnea Detection Based on Thoracic and Abdominal Movement Signals of Wearable Piezo-Electric Bands[6]. The use of a piezoelectric sensor on the device is placed in the position of the chest cavity and abdominal cavity, it turns out to produce different pressure measurement results, meaning that the difference in the position of the sensor affects the pressure measurement results[7][8]. However, in his journal only explained that piezoelectric sensors can be used to detect sleep apnea by using piezoelectric sensors on the chest and abdomen, so in his research this tool did not display the value of breaths per minute.

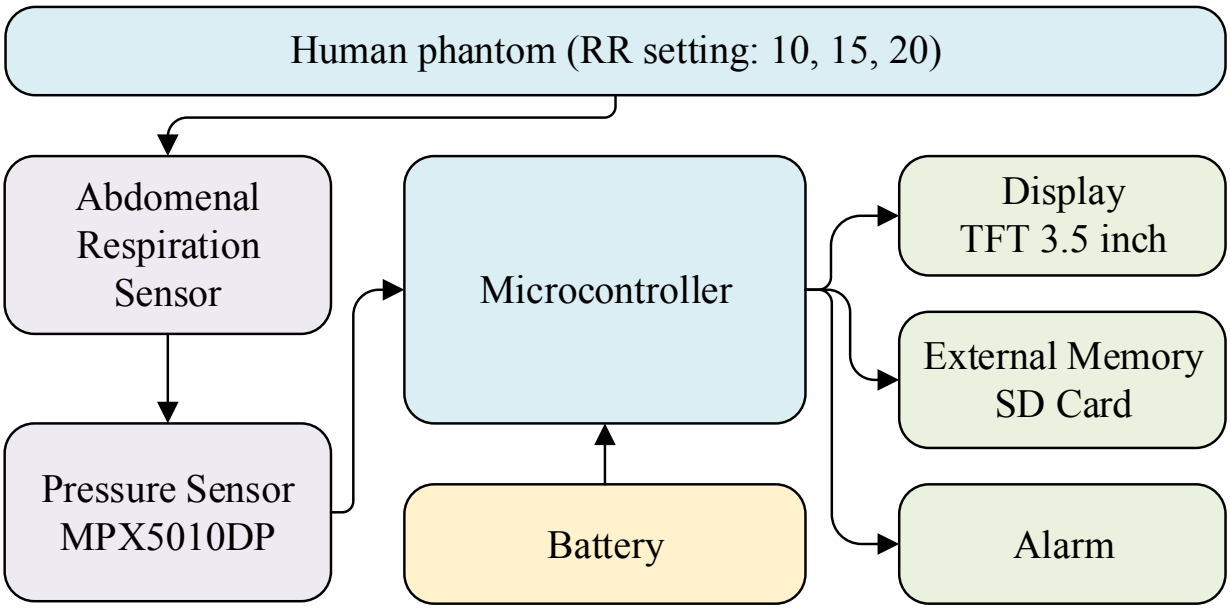

FIGURE 1 . The System Block Diagram in research with using Abdominal Respiratory Sensor and Pressure Sensor

Later in the same year, Erdenepay, et al made an Obstructive Sleep Apnea Screening Using a Piezo-Electric[9] Sensor[10], this tool detects sleep disturbances (apnea)[11] through the incidence of snoring using a piezoelectric sensor mounted on the neck. Snoring will cause vibrations, where the vibration can be detected on the sensor, in addition to snoring the piezoelectric sensor can also measure the vibrations generated by body movements and coughing during the patient's sleep.

Breathing is made possible by the work of the diaphragm and external intercostal muscles. The diaphragm contracts and moves downwards creating a pressure difference that causes air to enter the lungs[8][12][6]. Contraction of the intercostal muscles causes the ribs to lift which results in expansion of the chest cavity allowing a greater volume of air to enter[13][14]. The process of this pressure change can be seen from changes in the position of the chest that expands and deflates and changes in that position can be detected with abdominal sensors and pressure sensors, abdominal sensors and pressure sensors, namely sensors that can detect changes in pressure when inspiration and expiration occur [15][16][17]. This sensor has advantages such as a small sensor shape, and easy use. This sensor has also been applied to detect and even monitor respiration values, but discussions and research on abdominal sensors are still difficult to find even though abdominal sensors have been used directly on patients to determine the condition of apnea.

So far, the average research tool uses a piezoelectric transducer which has several drawbacks, one of which is that it does not display the value of breaths per minute[18][18]. With the apnea condition monitoring device using an abdominal respiratory sensor with an IoT system, it is hoped that the patient's condition can quickly be known how many times he is in apnea condition[19][20]. Thus minimizing the occurrence of delays in handling which can be fatal. Based on problems in the field so far, there are shortcomings, namely user ignorance when the abdominal respiratory sensor hardens is not immediately replaced so that when the patient does not experience apnea, the sensor will continuously detect apnea until the sensor is replaced with a new one.

Based on the research that has been done previously and the lack of research and discussion that discusses the abdominal sensor, the author will make a study entitled "Analysis of Abdominal Respiratory Sensor Performance in Apnea Conditions with SD Card Storage" which is the development of research that has been carried out. previously made. This study was conducted to test and use the Abdominal Respiratory Sensor and MPX5010DP[21], [22] Pressure Sensor for Apnea Monitoring

II. METHODHOLOGY

The measurement of this module was carried out with the aim of testing the Abdominal Respiratory Sensor to detect breathing in patients who were simulated with a simulator continuously for 3 days and monitored for 14 hours. Measurement of this module is carried out by installing sensors on the simulator with RR settings of 10, 15, and 20 to see the response of the Abdominal Respiratory[23][24][25]

Sensor to the patient's breathing, which is then read by the pressure sensor. in this study using a simulator in the form of a servo motor that has been programmed using an arduino connected to an arduino nano with 15, 20 to 25 revolutions per minute. rounds every minute is like RR to humans

The research design used in making the module is Pre-experimental with the After Only Design type. In this design the researcher only uses one group of subjects and only sees the results without measuring and knowing the initial conditions, but there is already a comparison group.

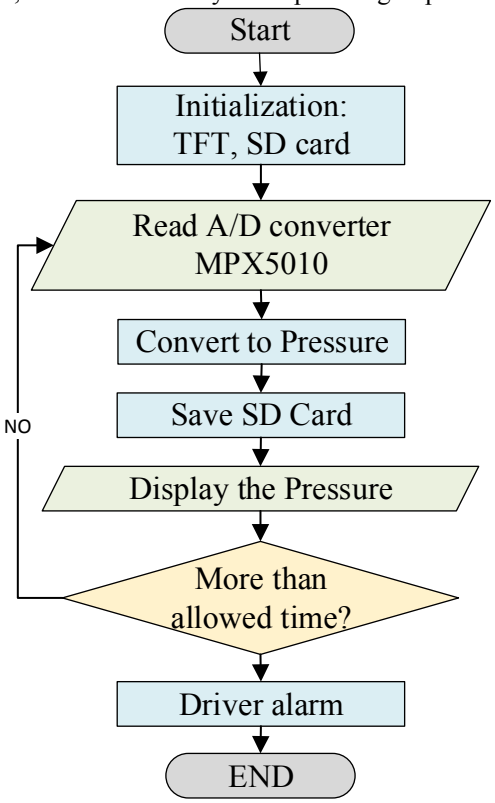

FIGURE 2 . The Flowchart System in research with using Abdominal Respiratory Sensor and Pressure Sensor

The independent variable in this study was respiration. the dependent variable is the pressure sensor MPX5010dp. As a controlled variable in this study is the Arduino microcontroller board[26]. This paragraph can explain **FIGURE 1** when the abdominal sensor is attached to the diaphragm, there will be pressure during inspiration and expiration which will be received by the pressure sensor, from the pressure sensor it will read how much pressure is received and will be forwarded to Arduino and will be read so that it appears on the RR (Response Rate) display and The graph as well as the pressure received by the sensor will be detected. When inspiration and expiration do not occur, a 10 minute interval will be given to ensure the patient is truly apnea or not, if the 10 minute period has passed and there are no signs of breathing, the alarm will activate to indicate that the patient has apnea with simultaneously sent a notification to the doctor that the patient has apnea.

Refer to **FIGURE 2** when the abdominal sensor is installed in the diaphragm position, it will initialize and will read the patient's respiration, the data will be stored on the SD Card which will then be displayed on the layer, if there is no apnea it will return to the patient's respiration reading and if there is apnea, a time lag appears until it passes time out an alarm will appear along with sending a notification.

A. DATA ANALYSIS

Measurement of this module is carried out by installing sensors on the simulator with RR settings of 10, 15, and 20 to see the response of the Abdominal Respiratory Sensor to the patient's breathing, which is then read by the pressure sensor. The measurement of this module was carried out with the aim of testing the Abdominal Respiratory Sensor to detect breathing in patients who were simulated with a simulator continuously for 3 days and monitored for 14 hours. The average value of the measurement is obtained by using the mean or the average by applying equation (1). The average is the number obtained by dividing the number of values by the number of data in the set.:

$$\overline{x} = \frac{x1+x2...+xn}{n} \quad (1)$$

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

$$\mathrm{SD} = \sqrt{\frac{\sum(xi-\overline{x})^2}{(n-1)}} \quad (2)$$

where xi indicates the number of desired values, x indicates the average of the measurement results, n indicates the number of measurements. Uncertainty (UA) is a doubt that appears in each measurement result[26][18][27]. The uncertainty formula is shown in the equation (3):

$$UA = \frac{SD}{\sqrt{n}} \quad (3)$$

where UA indicates the uncertainty value of the total measurement, SD indicates the resulting standard deviation, and n indicates the number of measurements. %error indicates a system error. The lower Error value is the average difference of each data. Errors can indicate deviations between the standard and the design or model. The error formula is shown in the equation (4).

$$\%\mathrm{ERROR} = \frac{(x_n - x)}{x_n} \times 100\% \quad (4)$$

where xn is the measured value of the machine calibrator. X is the measured value of the design.

III. RESULT

In this study, the module has been tested using a comparison tool. Designs featured in **FIGURE 3.** The power supply circuit is made using 1 18650 battery which is arranged in parallel with 1 output that will go to 2 step up modules. The output of the first step up module is +12V which will enter the Arduino which is used as a voltage source for the entire circuit.

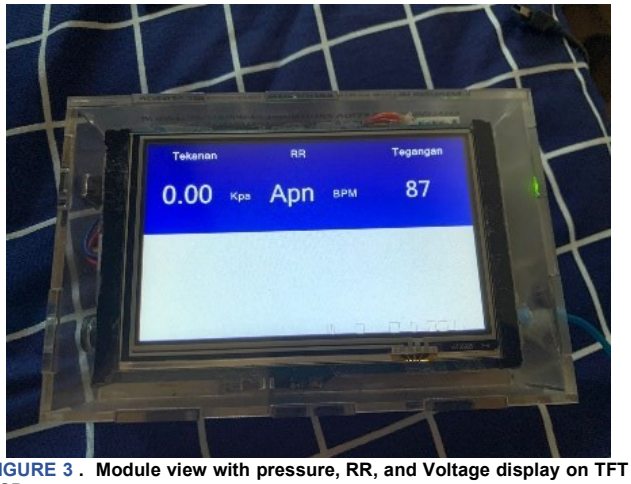

FIGURE 3 . Module view with pressure, RR, and Voltage display on TFT LCD

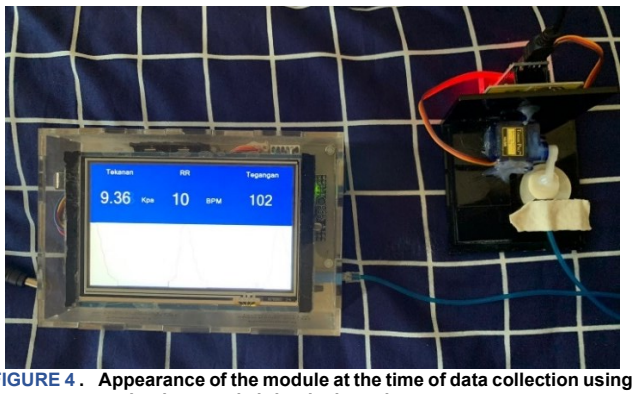

FIGURE 4 . Appearance of the module at the time of data collection using a servo motor simulator and abdominal respiratory sensor

In **FIGURE 4** this research was conducted at the Department of El The Abdominal Respiratory Sensor is a small sensor pad attached to the pressure sensor via several tubes. This sensor will be installed on the simulator to detect a breathing simulation which will affect the resulting pressure. The pressure generated by the Abdominal Respiratory Sensor will later be read by the MPX5010DP Pressure Sensor and then processed on the Arduino Mega microcontroller.

Electromedical Technology, Health Polytechnic, Ministry of Health, Surabaya. This study uses a respiration simulator that can be adjusted to the RR value as a substitute for the patient. This research will be carried out in 2 stages, namely use for 3 days and 1 week or 7 days. In use for 3 days, the module will be monitored every 14 hours. The RR settings used are 10, 15, and 20. Here are the measurement data results obtained in 3 days of use. This explanation can be referred to in **TABLE 1.** Based on the table above, for 3 days the RR value which is monitored every 14 hours looks in accordance with the RR simulator settings. So, it can be said that the sensor can still work to detect RR according to the simulator settings. However, for 3 days or 70 hours there was a decrease in pressure output from the Abdominal Respiratory Sensor which was read by the MPX5700 pressure sensor so that it affected the voltage output from the pressure sensor every 14 hours of monitoring. This pressure drop will then be analyzed further. As for usage for 1 week, the module will be monitored once a day. The RR setting used is 15. Here are the results of the measurement data obtained in 1 week of use.

TABLE 1
Measurement Results of Abdominal Respiratory Sensor Output and Pressure Sensor During 3 Days Monitoring

Setting RR	Result	Trial (hour)	Pressure		Voltage	
			Insp.	Exp.	Insp.	Exp.
10	10	14	10.6	0	121	82
	10	28	9.8	0	115	82
	10	42	8.9	0	111	82
	10	56	8.7	0	107	82
	10	70	8.4	0	105	82
15	15	14	10.8	0	122	82
	15	28	9.5	0	114	82
	15	42	8.9	0	112	82
	15	56	8.4	0	109	82
	15	70	7.9	0	105	82
20	20	14	11.1	0	122	82
	20	28	8.9	0	112	82
	20	42	7.9	0	105	82
	20	56	7.4	0	102	82
	20	70	6.1	0	98	82

TABLE 2
Measurement Results of Abdominal Respiratory Sensor Output and Pressure Sensor During 1 Week Monitoring

Setting RR	Result	Trial	Pressure		Voltage	
			Insp.	Exp.	Insp.	Exp.
15	15	Day 1	9.7	0	114	82
	15	Day 2	8.7	0	109	82
	15	Day 3	7.9	0	101	82
	14	Day 4	7.2	0	103	82
	12	Day 5	5.5	0	94	82
	9	Day 6	3.7	0	88	82
	7	Day 7	2.5	0	83	82

This explanation can be referred to in **TABLE 2.** Based on the table above, for the first 3 days in 1 week of using the module, the RR value monitored every 1 looks according to

the RR simulator settings. So it can be said that the sensor can still work to detect RR according to the simulator settings in the first 3 days. However, there was a change in the RR value that did not match the setting on the fourth day and continued to decline the next day. And still during those 7 days there was still a decrease in pressure output from the Abdominal Respiratory Sensor which was read by the MPX5700 pressure sensor, thus affecting the voltage output from the pressure sensor.

After getting the above results, it can be seen the error value and the suitability of the RR with the setting. The calculation of the error value this time is based on the output pressure reading at the beginning of monitoring which will then calculate the error value for decreasing the pressure output value in the next monitoring.

The calculation of the error value in the 3-day monitoring will take the pressure output value in the first 14 hours of monitoring as a benchmark. The following is the error result for each decrease in pressure output on the Abdominal Respiratory Sensor for 3 days at each RR setting:

TABLE 3
Result of Error Value For Each Pressure Drop On Abdominal Respiratory Sensor In 3 Days Of Use

Setting RR	Trial	Pressure Value	Pressure Drop Error (%)	Average Error Score (%)
10	28 hour	9.8	0.07547	0.15566
	42 hour	8.9	0.16038	
	56 hour	8.7	0.17925	
	70 hour	8.4	0.20755	
15	28 hour	9.5	0.12037	0.19676
	42 hour	8.9	0.17593	
	56 hour	8.4	0.22222	
	70 hour	7.9	0.26852	
20	28 hour	8.9	0.1982	0.31757
	42 hour	7.9	0.28829	
	56 hour	7.4	0.33333	
	70 hour	6.1	0.45045	

This explanation can be referred to in **TABLE 3.** Based on the table above, it can be seen that every 14 hours there is a decrease in the pressure value at the output of the Abdominal Respiration Sensor. Due to the decrease in the output value, it is possible to find the error value of each decrease. In the experimental setting of RR 10, it is seen that the initial error on the 2nd monitoring at 28 hours is still ±0.075% of the initial pressure output reading. The error value then gets bigger with the largest error value at 70 hours, which is ±0.207% of the initial pressure output reading. Meanwhile, in setting RR 15, the error value at 28 hours is ±0.12% and the error value at 70 hours is ±0.268%. And at the RR 20 setting the error value at 28 hours is ±0.19% and the error value at 70 hours is ±0.45%.

When viewed based on the average error of the RR setting, the error value in the RR 10 setting is ±0.156%, the RR 15 setting is ±0.197%, and the RR 20 setting is ±0.318%. From the average error value, it can be said that the higher the RR setting value, the higher the average error for each drop in output pressure.

Then, here are the error results for each decrease in pressure output on the Abdominal Respiratory Sensor for 3 days at each RR setting:

TABLE 4
Result of Error Value for Each Pressure Drop on Abdominal Respiratory Sensor In 1 Week of Use

Setting RR	Trial	Pressure Value	Pressure Drop Error (%)	Average Error Score (%)
15	Day 2	8.7	0.10309	0.39003
	Day 3	7.9	0.18557	
	Day 4	7.2	0.25773	
	Day 5	5.5	0.43299	
	Day 6	3.7	0.61856	
	Day 7	2.5	0.74227	

This explanation can be referred to in **TABLE 4.** Based on the table above, it can be seen that every 1 day there is a decrease in the pressure value at the output of the Abdominal Respiration Sensor. In the experimental setting of RR 10, it can be seen that the initial error on the 2nd day of monitoring is still ±0.103% of the initial pressure output reading. The error value then gets bigger on the 3rd day, which is ±0.186% of the initial pressure reading. Then on the 4th day ±0.258%, on the 5th day ±0.432%, on the 6th day ±0.619, then the biggest error on the 7th day is ±0.742%. The average error in the 1-week test is also greater than the 3-day test, which is 0.39%. This means that the sensor performance drops dramatically in 1 week of use.

When using the module for 3 days, for 3 days the RR value which is monitored every 14 hours looks in accordance with the RR setting of the simulator. So, it can be said that the sensor can still work to detect RR according to the settings of the simulator. However, for 3 days or 70 hours, there is a decrease in the pressure output from the Abdominal Respiratory Sensor which is read by the MPX5010DP pressure sensor so that it affects the voltage output from the pressure sensor every 14 hours monitoring. Due to a decrease in the value of the output, it is possible to find the error value of each decrease. In the experimental setting of RR 10bpm, it can be seen that the initial error on the 2nd monitoring at 28 hours is still ±0.075% of the initial pressure output reading. The error value then gets bigger with the largest error value at 98 hours, which is ±0.254% of the initial pressure output reading. While the RR setting of 15bpm, the error value at 28 hours is ±0.12% and the error value at 98 hours is ±0.361%. And at the 20bpm RR setting, the error value at 28 hours is ±0.19% and the error value at 98 hours is ±0.54%.

When viewed based on the average error, the error value at the RR 10bpm setting is ±0.185%, at the RR 15 setting ±0.245%, and at the RR setting 20bpm it is ±0.383%. From the average error value, it can be said that the higher the RR setting value, the higher the average error for each decrease in pressure output. Thus, the value of the pressure output drop is further away from the initial measurement value and the performance of the sensor is decreasing.

Whereas in the use of the module for 1 week, during the first 3 days of 1 week of using the module, the RR value monitored every 1 appears to match the RR setting of the simulator. So, it can be said that the sensor can still work to detect RR according to the settings of the simulator in the first 3 days. However, there was a change in the RR value that did not match the setting on the fourth day and continued to decline the next day. And still during those 7 days, the pressure output from the Abdominal Respiratory Sensor continued to decrease which was read by the MPX5010DP pressure sensor, thus affecting the voltage output from the pressure sensor. In the experimental setting of RR 10, it can be seen that the initial error on the 2nd day of monitoring is still ±0.103% of the initial pressure output reading. The error value then gets bigger on the 3rd day, which is ±0.186% of the initial pressure output reading. Then on the 4th day ±0.258%, on the 5th day ±0.432%, on the 6th day ±0.619, and then the biggest error on the 7th day is ±0.742%. The average error in the 1-week test is also greater than the 3-day test, which is 0.39%. This means that the performance of the sensor decreases considerably at 1 week of use.

In terms of the suitability of the RR on the module with the RR on the simulator, in the first 3 days, the module still shows a match between the RR value read and the RR setting from the simulator. However, on the fourth day to the seventh day, there was a discrepancy between the RR that was read and the RR setting on the simulator. If we look at the Abdominal Respiratory Sensor pressure output data, on the fourth day it has an output pressure of 7.2 kPa. The RR value will decrease from day to day, until on the seventh day it gets a value of 7 kPa. With this it can be said that the pressure output from the Abdominal Respiratory Sensor will continue to decrease which affects the RR reading on the module which can only be adjusted until the 3rd day. Then, in the following days, the module readings will continue to decrease, which means the sensor's ability is decreasing.

In **FIGURE 5** Based on the table and graph below, it can be seen that in every 1 day, there is a decrease in the pressure value at the output of the Abdominal Respiratory Sensor. Due to a decrease in the value of the output, it is possible to find the error value of each decrease. The longer the time, the greater the error value and the lower the pressure output. In the experimental setting of RR 10bpm, it can be seen that the initial error on the 2nd day of monitoring is still ±0.103% of the initial pressure output reading. The error value then gets bigger on the 3rd day, which is ±0.186% of the initial pressure output reading. Then on the 4th day ±0.258%, on the 5th day ±0.432%, on the 6th day ±0.619, and then the biggest error on the 7th day is ±0.742%. The average error in the 1-week test is also greater than the 3-day test, which is 0.39%. This means that the performance of the sensor decreases considerably at 1 week of use.

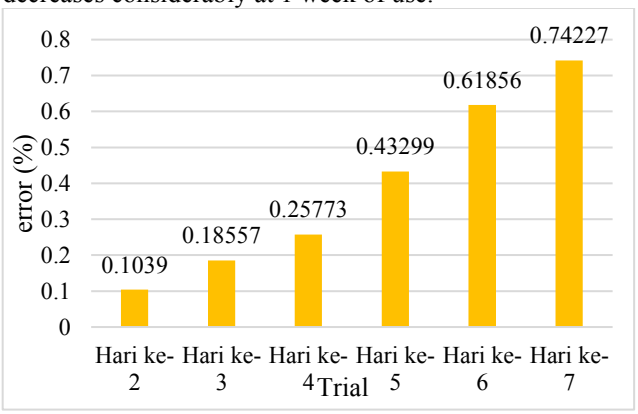

FIGURE 5 . Error on Pressure Drop (%) at Setting RR 15 BPM

This paragraph can explain **FIGURE 6** in the picture above, it can be seen that when setting 10 BPM the distance between signals is tenuous caused by the distance between the sensor pressure at 10 BPM setting, this condition causes the sensor to last longer than the 15 and 20 BPM settings.

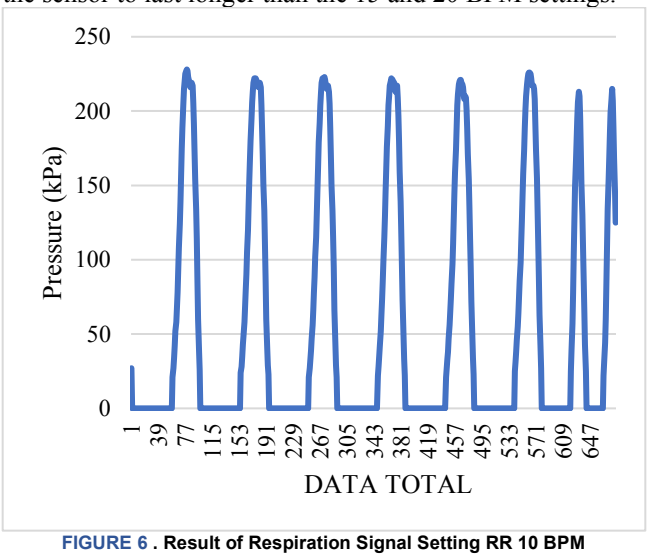

FIGURE 6 . Result of Respiration Signal Setting RR 10 BPM

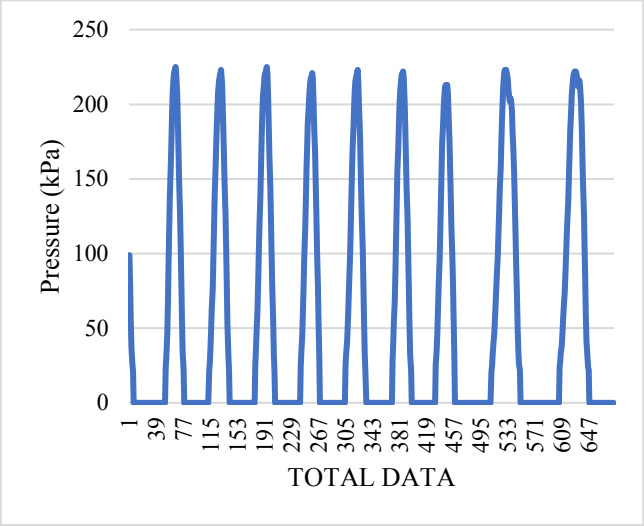

FIGURE 7 . Respiration Signal Results Setting RR 15 BPM

This paragraph can explain **FIGURE 7** in the picture above, it can be seen that when setting 15 BPM, the distance between the signals is closer than the setting at 10 BPM, which is caused by the time the sensor is depressed faster than the 10 BPM setting, this condition causes the sensor to be damaged more quickly than the previous setting.

This paragraph can explain **FIGURE 8** in the picture below it can be seen that when setting 20 BPM the distance between the signals is getting closer than the settings at 10 and 15 BPM which is caused by the time the sensor is depressed faster than the 10 and 15 BPM settings, this condition causes the sensor to be damaged faster than the previous setting. .

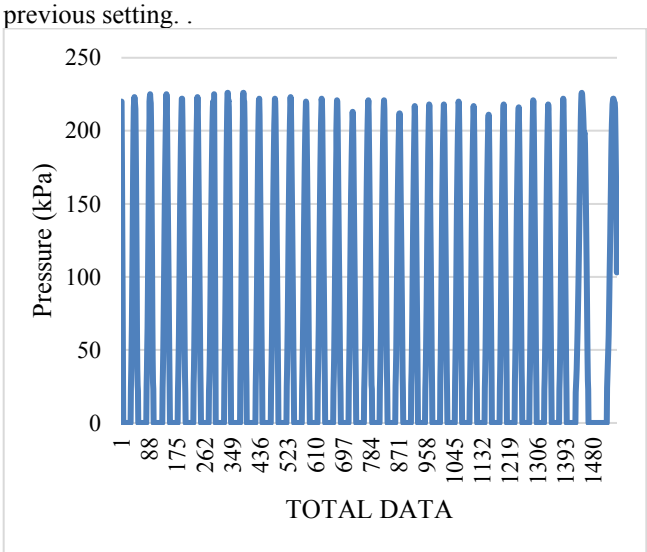

FIGURE 8 . Result of Respiration Signal Setting RR 20 BPM

IV. DISCUSSION

After testing the module, data collection and analysis of the results are carried out to determine the stability and accuracy of making the module. This study also aims to analyze the use of the Abdominal Respiratory Sensor and MPX5010DP Pressure Sensor. After the experiment was carried out in the study, the results obtained on the ventilator were as follows:

When using the module for 3 days, for 3 days the RR value which is monitored every 14 hours looks in accordance with the RR setting of the simulator. So, it can be said that the sensor can still work to detect RR according to the settings of the simulator. However, for 3 days or 70 hours, there is a decrease in pressure output from the Abdominal Respiratory Sensor which is read by the MPX5010DP pressure sensor so that it affects the voltage output from the pressure sensor every 14 hours monitoring. Due to a decrease in the value of the output, it is possible to find the error value of each decrease. In the experimental setting of RR 10bpm, it can be seen that the initial error on the 2nd monitoring at 28 hours is still ±0.075% of the initial pressure output reading. The error value then gets bigger with the largest error value at 98 hours, which is ±0.254% of the initial pressure output reading. While the RR setting of 15bpm, the error value at 28 hours is ±0.12% and the error value at 98 hours is ±0.361%. And at the 20bpm RR setting, the error value at 28 hours is ±0.19% and the error value at 98 hours is ±0.54%.

When viewed based on the average error, the error value at the RR 10bpm setting is ±0.185%, at the RR 15 setting ±0.245%, and at the RR setting 20bpm it is ±0.383%. From the average error value, it can be said that the higher the RR setting value, the higher the average error for each decrease in pressure output. Thus, the value of the pressure output drop is further away from the initial measurement value and the performance of the sensor is decreasing.

Meanwhile, in the use of the module for 1 week, during the first 3 days of 1 week of using the module, the RR value monitored every 1 appears to match the RR setting of the simulator. So, it can be said that the sensor can still work to detect RR according to the settings of the simulator in the first 3 days. However, there was a change in the RR value that did not match the setting on the fourth day and continued to decline the next day. And still during those 7 days, the pressure output from the Abdominal Respiratory Sensor continued to decrease which was read by the MPX5010DP pressure sensor, thus affecting the voltage output from the pressure sensor. In the experimental setting of RR 10, it can be seen that the initial error on the 2nd day of monitoring is still ±0.103% of the initial pressure output reading. The error value then gets bigger on the 3rd day, which is ±0.186% of the initial pressure output reading. Then on the 4th day ±0.258%, on the 5th day ±0.432%, on the 6th day ±0.619, and then the biggest error on the 7th day is ±0.742%. The average error in the 1-week test is also greater than the 3-day test, which is 0.39%. This means that the performance of the sensor decreases considerably at 1 week of use.

In terms of the suitability of the RR on the module with the RR on the simulator, in the first 3 days, the module still shows a match between the RR value read with the RR setting from the simulator. However, on the fourth day to the seventh day, there was a discrepancy between the RR that

was read and the RR setting on the simulator. If we look at the Abdominal Respiratory Sensor pressure output data, on the fourth day it has an output pressure of 7.2 kPa. The RR value will decrease from day to day, until on the seventh day it gets a value of 7 kPa. With this it can be said that the pressure output from the Abdominal Respiratory Sensor will continue to decrease which affects the RR reading on the module which can only be adjusted until the 3rd day. Then, in the following days, the module readings will continue to decrease, which means the sensor's ability is also decreasing.

Some studies conclude that sleep apnea has a serious impact on patients, especially it can cause heart problems (hypertension, coronary artery disease, and arrhythmias). In addition, disruption of the sleep cycle can also have a negative impact on quality of life. This often causes depression, daytime fatigue and sleepiness. Then with the use of the abdominal respiratory sensor, the sensor is no longer elastic, the pressure difference generated by the sensor will be unstable so that the sensor cannot work optimally. Given these conditions, the period of use of the sensor needs to be known how durable the sensor is when it is used on patients so that the sensor can maximally detect the occurrence of apnea in neonates. with some limitations of the problems in this study such as the method of data collection which directly still does not use humans as a method of data collection.

The implications of this research are used to help facilitate medical personnel or equipment operators in monitoring the abdominal breathing sensor. When the sensor is no longer elastic, the pressure difference generated by the sensor will become unstable so that the sensor cannot work optimally. Given these conditions, the period of use of the sensor needs to be known how long the sensor is when used on patients so that the sensor can maximally detect the occurrence of apnea in neonates. Researchers will analyze a combination of abdominal sensors and pressure sensors to monitor apnea. Due to various factors, the module made by the author is still far from perfect, both in terms of planning, manufacturing, and how the module works, so there are several shortcomings that have been analyzed from the tool that the author made. the first is a simulator that still uses servo motors, then the results of a fairly large error using the MPX5010dp pressure sensor and there is still a lack of monitoring because the data is only stored in the sd card module.

Based on the research that has been done previously and the lack of research and discussion that discusses the abdominal sensor, the author will make a study entitled "Analysis of Abdominal Respiratory Sensor Performance in Apnea Conditions with SD Card Storage" which is the development of research that has been carried out. previously made.

IV. CONCLUSION

This research was conducted to test and use the Abdominal Respiratory Sensor and Pressure Sensor MPX5010DP in Apnea Monitoring, it can be concluded that. The performance of the use of the Abdominal Respiratory Sensor and Pressure Sensor on the Apnea Monitoring module functions well in detecting RR according to the settings on the simulator for 3-day monitoring. Testing on the fourth day and so on was not good because the RR that was read was not in accordance with the settings. In monitoring for 3 days, the pressure output from the Abdominal Respiratory Sensor continued to decrease every 14 hours with the largest average error value of ±0.318% at the RR setting of 20bpm. Then, in monitoring for 1 week, the average error value in this test is ±0.39%. The Arduino Mega microcontroller module is used to process the output generated by the sensor and sends data to the TFT LCD to display graphs as well as the pressure, voltage, and RR values. And the sensor reading program until delivery to the TFT LCD is made using the Arduino IDE application. The development that can be done in this research is to use a more sensitive pressure sensor so that the results obtained are more stable and make the module display more attractive.

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