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Implementation of a Microcontroller Arduino for Portable Peak Expiratory Flow Rate to Examine the Lung Health

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ABSTRACT A peak flow meter will measure the ability to push air out of the lungs; the lungs are one of the body's most vital organs. The commonly used method is to deploy a peak flow meter, which uses mechanical systems. This mechanical system is prone to a high error rate of reading, and as a result, a more accurate and reliable means becomes inevitable. This paper describes the design and implementation of a micro-controller-based portable peak flow meter, which can be used to provide accurate data for the diagnosis of asthma, bronchitis, and emphysema. In the heart of the system are the programmable Mega Arduino microcontroller and a device called MPX5100GP sensor, which has a pressure range of 0-100 Kpa to detect a patient breath. The device was equipped with a display facility, which uses Nextion touch TFT output to display related tests and examinations. There is also a provision to store the results data using SD Card, while a printer prints the test results for further diagnostic purposes. An experimental setup in the laboratory shows that the designed micro-controller-based PFM shows that the error rate was between 0.50 % and 4.21 % compared with the mechanical-based peak flow meter. The application of micro-controller-based peak flow meters also allows real-time and remote monitoring of peak flow parameters. The evolution of modern technology has made the possibility of developing a micro-controller based portable, peak flow meters, which can be used to measure the data involved in the diagnosis of lung-related diseases more accurately.

INDEX TERMS Microcontroller, Peak Flow Meter, Peak Expiratory Flow Rate, PEFR, MPX5100GP

I. INTRODUCTION

The lungs are one of the most important organs in the human body, in which a respiration process occurs. Disruption of the respiration process greatly affects the capacity and volume value of the lungs. Basically, the capacity and volume of the lungs is influenced by a person's age and gender; however, a person's work, activity, disease and weight can also affect the capacity and volume of a person's lungs. Asthma is a globally significant non-communicable disease with major public health consequences for both children and adults, including high morbidity and mortality in severe cases[1].Asthma is characterized by variable airflow obstruction, often the worst at night or when it arises[2]. Bronchial asthma is a disease that causes significant morbidity and mortality. It is projected to increase at an alarming rate with an estimated prevalence of 400 million by 2025, in contrast to the current 300 million. Peak flow meters are one of the three simplest ways to assess and monitor airway function objectively, the use of peak flow meters is also being strongly recommended for monitoring asthma while standard pulmonary function tests, such as spirometry, can be of limited use in clinical settings[3]. In general, it is believed that between 50 and 75% of asthmatic patients can be considered to have mild asthma[4]. According to data from the Global Initiative for Asthma (GINA, 2015), 300 million people worldwide have bronchial asthma in various age groups and increasingly, especially in developed countries. According to the Global Initiative for Asthma[5],asthma is a major public health problem worldwide. There are 300 million asthmatics worldwide, and is expected to increase to 400 million by 2025. One in 250 people who die is asthmatic and about 180,000 deaths per-4 years are caused by asthma with the most deaths at the age of > 45. In Indonesia, asthma is included in the top ten causes of pain. It is estimated that the prevalence of asthma in Indonesia is 5% of the entire population of Indonesia, meaning there are 12.5 million asthma patients in Indonesia (Zibetra 2015). The World Health Organization (WHO) estimates the incidence of respiratory tract infections in developing countries with a mortality rate of 15 percent-20 percent per year by toddler age. In Indonesia, respiratory tract infections always rank first in infant and toddler mortality. Based on the prevalence of Respiratory Tract Infections in 2016 in Indonesia has reached 25 percent with a range of events that is about 17.5 percent-41.4 percent with 16 provinces of which have a prevalence above the national figure. In addition, respiratory infections are also often on the list of the top 10 diseases in hospitals. Measurement of peak expiratory flow rate (PEFR) is required for effective asthma treatment and to know the development of asthma therapy effectiveness[6]. In addition to using treatment *therapy, monitoring* asthma control can be done by examining pulmonary function. It is measured with a peak flow meter, a simple, portable handheld device used to monitor a person's ability to eject air out through the bronchi. Thus, it can explain the level of obstruction in the airways[7][8]. Home care includes self-monitoring using a peak expiratory flow (PEF) tool and a written asthma action plan[9]. International guidelines for asthma self-management recommend the use of a peak flow meter for coagulation of lung function at home[10].Upper airway obstruction is a state of inhibition Airway begins nasal sample larynx and trachea upper part. Partial or total airway blockages should be above immediately, as it can result in permanent brain damage and even death. The success of management should begin with careful, thorough and rapid evaluation of the airway for the identification of various causal factors. Based on the clinic's symptoms, the level and gradation of blockage can be determined, it is necessary to determine the initial therapy that can be done[11]. Asthmatics uses the device to monitor their condition according to an asthma action plan developed by a service provider that includes self-monitoring of airway obstructions or symptoms. Using *PEFR* measurements is more economical and more widely available, therefore it is proposed as an alternative to spirometry[12]. Peak flow meter is a tool used to measure the amount of airflow in the human airway or often referred to as PFR (Peak Flow Rate). Peak Flow Rate (PFR) measurement is a simple and reliable way to detect airway obstruction[13]. PEFR is the maximum rate of airflow achieved during forced expiation after maximum inspiration[14]. Peak Expiration Current (APE) is the maximum flow rate produced during strong breathing, starting with full lung inflation. The peak flow rate reflects the flow of a large airway and depends on the strength of the subject. This peak flow rate measures airflow through the pulmonary bronchi and obstruction rate in the airways[15][16]. Peak expiration flow rate depends on several variables including airway resistance, maximum voluntary muscle effort and possible compression effect of maneuvering on the thoracic airways[17]. The severity of the disorder that occurs can be assessed by lung function test, namely by spirometry examination and Examination of Peak Flow (APE) using *Peak Expiratory Flow* meter*(PEF* meter). PEFR measurement is a simple, non-invasive, fast and economical method to assess the strength and speed of expiration in L/min, through the maximum expiration of total pulmonary capacity[18]. Measurement through peak flow meter produces readings in 3 categories, according to the article the peak flow meter and its use in clinical practice by B O Adenlyl and G E Erhabor namely green zone, yellow zone and red zone. The green zone shows that the patient's condition is good with peak flow worth more than equal to 80%. Yellow zone means the patient is in a state of alert, this can be caused by the patient experiencing 7 some symptoms before asthma relapse due to exposure to asthma triggers with a peak flow value between 50% - 79%. While the red zone indicates the patient needs further action with a peak flow measurement result of less than 50%. In the studies that have been done it can be concluded that there is no significant difference in the average PEFR value of peak flow meters and spirometers. Therefore, peak flow meters can be used as a cheap, safe, easy to use, and sensitive tool to assess obstructive airway diseases, where spirometry is not available[19].

The measurement of peak expiratory flow was pioneered by Martin Wright, , who produced the first measurement tool specifically designed to measure this index of lung function. Since the original instrument design was introduced in the late 1950s, development has continued to a more portable and lower cost version[20].There in 2011 peak flow *meter* made by Dersthya Yulren Banya with microcontroller-based AT89S51 and subsequently, developed by Devie Muslimatun Nisa in 2012 equipped with Normal /abnormal *PEFR* value. In both studies, the cooling fan rotation produced DC voltage to detect incoming airflow, but the use of DC *Fan* made the data obtained less accurate. Next in 2015, developed *the peak flow meter* digital tool using mpx5100 pressure sensor by Indah Lindari. Weaknesses in the tool have not been applied data storage inspection results. Ika Safitri in 2017 also developed the tool equipped with *SD Card Storage,* but the tool does not classify the diagnosis results inpatients[21]. Then in 2019, a peak flow meter tool was developed equipped with indicators of inspection results by Nadiya Garnis Sallyfan. The disadvantage of the tool is that it cannot be used *portable* because the tool must be connected to the PC to display the results of the examination[22]. In 2020, Anisa developed the tool equipped with Inspection and Storage, but the tool was unable to display graph data of the inspection results[23].

Based on the description of the literature study that has been described, there are several things that need to be improved from previous research. In previous studies, the tool has not been able to display graphic data on the results of the examination and the display is less communicative. The results obtained from the examination can only be stored using an SD card that must be displayed on a PC, and cannot be printed to get data in the form of hard files directly.

Therefore, in this study, a Portable Peak Flow Meter with TFT features will be designed which is equipped with storage and printers with the aim of facilitating patient use with a portable device design and making it easier to evaluate examination results through graphs of examination results that are displayed in real time on the TFT, data storage on SD Card, and printer for further analysis purposes.

II. MATERIALS AND METHOD

A. EXPERIMENTAL SETUP

For the test of the read flow value on the display is done by using the compressor as the next input the results are read on the tool compared to the peak flow meter tool. For testing on patients, randomized testing was conducted on 11 respondents of different ages, genders, and genders. Each respondent was conducted as many as 3x examination in accordance with sop peak flow meter examination (FIGURE 1).

1) MATERIALS AND TOOL

This study used disposable disposable mouthpieces. The mouthpiece is used as an inflatable medium. MPX5100GP sensor as input sensor. Mega arduino microcontroller as a microcontroller used as system programming, unit conversion and displayed on TFT Nextion 4.2". Furthermore, peak flow meter is used as a comparison tool for the output of the tool.

2) EXPERIMENT

In this study, after the design is completed to be worked on, to ensure that the flow value applied in the module is the same as in the comparison is done the measurement of the flow value to the air exhaled from the compressor. Measurements are performed by applying the same compressor tube pressure from the module and the tool comparison (Peak Flow Meter). At the feasibility test stage the tool was randomly tested on 11 respondentts with 3x measurements per respondentt. Then the measurement results are compared to conventional Peak Flow Meter tools.

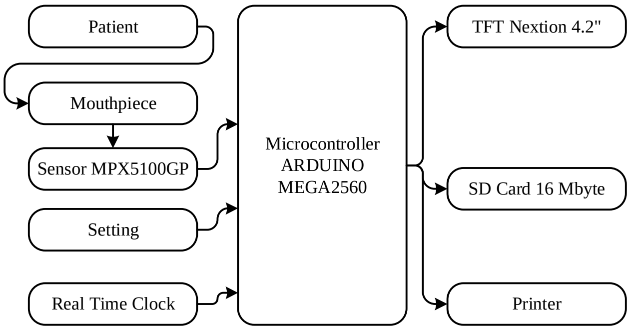

FIGURE 1. The Block Diagram of Peak Flow Meter

The patient will exhale as much as possible through the mouthpiece to be used as a sensor input. The output data from the sensor will be processed through data processing performed on the microcontroller. The processed data will also go to the RTC to perform the measurement time logging process. The measurement results will be displayed on the tool display in graphics, printed by the printer, and stored on the SD Card in txt form. These steps can be viewed according to FIGURE 1.

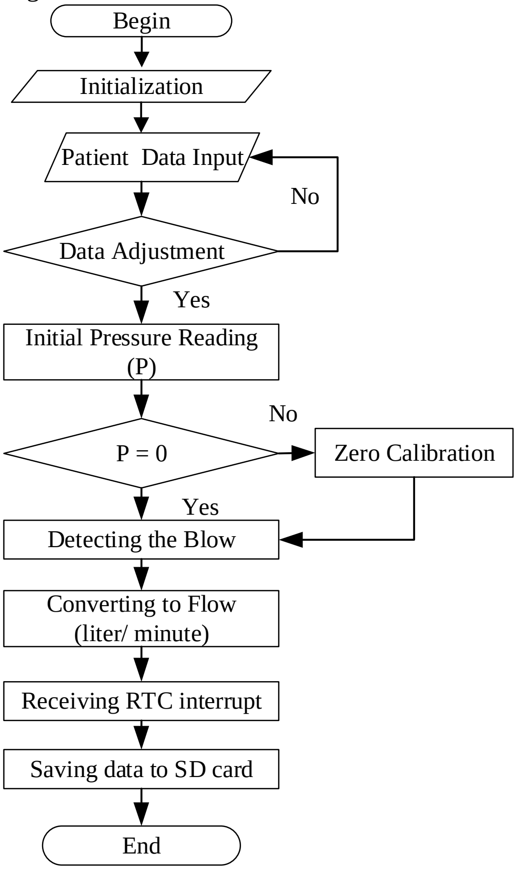

FIGURE 2. The Flowchart of The Arduino Program

Flow charts are based as shown in FIGURE 2. When the tool is turned on it starts with initialization. The patient enters data in the form of height, age and gender on the device. If the data is appropriate then on the display will show ready for inspection. The patient blows the mouthpiece, and then ADC data derived from the sensor output will be processed to determine the PEF value in the microcontroller. The data will be processed with RTC to know the measurement time and the data will be stored in SD Card in txt form and printed by the printer.

III. RESULT

In this research, a peak flow meter has been made with a display such as Fig 3, Portable Peak Flow Meter has been tested using a Conventional Peak Flow Meter. The results of the examination indicate that the results of these examinations can be used as a comparison.

A. PEAK FLOW METER DESIGN

Photos of the analog and digital sections of the Portable Peak Flow Meter are respectively shown in Fig 3. The analog section consists of four capacitors each of which has a different value for filtering sensor output and decoupling power supply. The digital part consists of the Arduino Mega 2560 microcontroller which is the main board, the micro SD Card module is used for data storage of the examination results, the RTC module, and the printer to print the examination results. This module uses a TFT Nextion display in Fig 4 that can display a graph of the examination examination in real time, examination results, normal values, and indications of examination results. Storage stored in the SD Card is saved in txt format. This format presents data on age, gender, height, and examination results, which will be processed into graphic data in the Ms. Excel application like shown in Fig 5. Thermal printers are used to print inspection results directly. Like in Fig 6 the printed data presents data on age, gender, height and examination results, and the date and time of the examination.

B. COMPARISON OF MEASUREMENT

Before measuring the respondent, the flow value of the air exhaled from the compressor is measured to ensure that the flow value displayed on the module is the same as in the comparison.TABLE 1 show the result of measurement of flow value at a pressure 0,7 kg/cm2 and TABLE 2 show the result of measurement of flow value at a pressure 1,4 kg/cm2 (FIGURE 3 and FIGURE 4).

TABLE 1
Result of measurement of flow value at a pressure 0,7 kg/cm^2

Compressor Pressure (kg/cm^2)	Comparison (L/Min)	Module (L/Min)	*Error* (%)
0,7	210	208	0,95
0,7	200	196	2,00
0,7	190	198	4,21
0,7	200	201	0,50
0,7	190	198	4,21
0,7	190	193	1,58

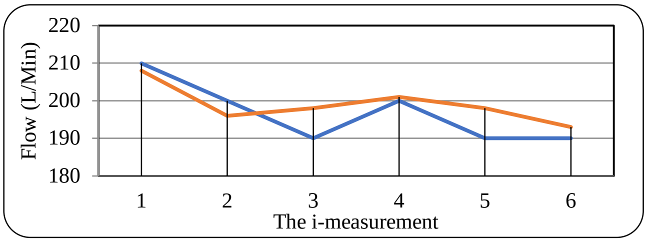

FIGURE 3. **Result of Measurement Of Flow Value At A Pressure 0,7 Kg/Cm2. (The orange line indicates the design and the blue line indicates the standard unit)**

TABLE 2
Result Of Measurement Of Flow Value At A Pressure 1,4 Kg/Cm^2

Compressor Pressure (kg/cm^2)	Comparison (L/Min)	Module (L/Min)	*Error* (%)
1,4	250	259	3,60
1,4	250	259	3,60
1,4	250	258	3,20
1,4	250	244	2,40
1,4	250	253	1,20
1,4	250	256	2,40

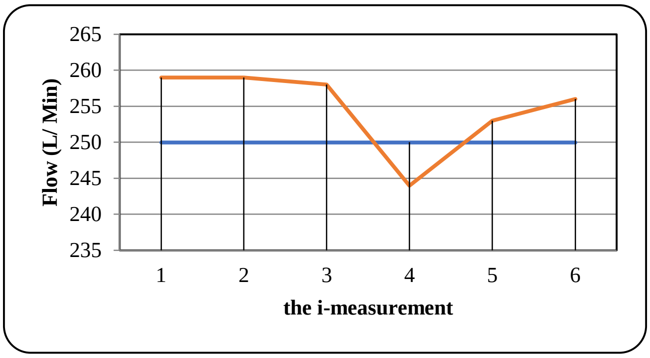

FIGURE 4. **Result Of Measurement Of Flow Value At A Pressure 1,4 Kg/Cm2. (The orange line indicates the design and the blue line indicates the standard unit)**

C. PEFR INSPECTION USING STANDARD

In reading the PEFR value, data were taken randomly on 11 respondents and each respondent took 3 measurements. the data taken is displayed in the TABLE 3, and FIGURE 5.

TABLE 3
Result of measurement of flow value at a pressure 0,7 kg/cm^2

Number of Respondent	Mean error (liter/minute)	Standard Deviation (liter/minute)
1	1.58	0.745
2	1.98	0.872
3	0.29	0.104
4	1.66	0.995
5	0.87	0.184
6	1.34	0.207
7	0.83	0.603
8	2.01	0.966
9	1.33	0.761
10	1.86	0.808
11	2.05	0.450

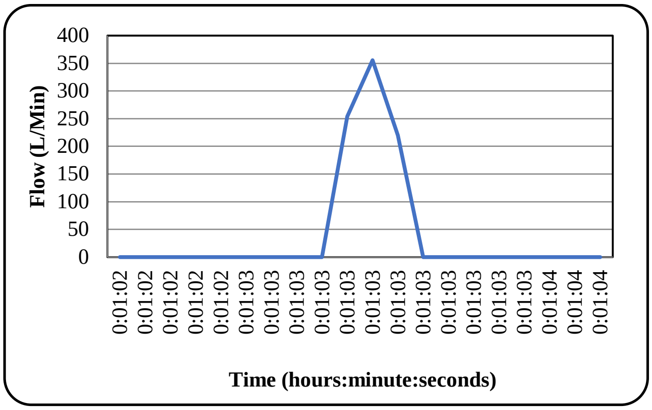

FIGURE 5. An example of PEFR graph from a respondent

IV. DISCUSSION

This module is equipped with a display using TFT Nextion which can display a graph of the examination in real time, examination results, normal values, and indications of examination results. TFT Nextion is used because it is more effective because it does not require external buttons to carry out the functions of this module. Controls on the module can be carried out directly on the Nextion touch screen and the display is wider so that it can display results more clearly. This module is also equipped with storage and time which is expected to be able to assist the diagnosis process which is continued by doctors or other health practitioners in monitoring the patient's condition. The data stored on the SD Card is in the form of data on age, gender, height and examination results, and the date and time of the examination in txt format. Through the data stored in the SD Card contained in the module, the doctor can find out the PEFR graph from the measurements made by the patient using Ms. Excel and is expected to help diagnose patients. This module is equipped with a thermal printer which is used to print the results of the inspection directly. The printed data presents data on age, gender, height and examination results as well as the date and time of the examination. The use of a thermal printer on this module is safer for the module design that is portable and can be carried anywhere. Before measuring the respondents. The author conducted a test on the module to ensure that the flow value displayed on the module was the same as in the comparison, by measuring the flow value of the air exhaled from the compressor. Measurements are made by providing the same compressor tube pressure from the module and comparison device (Peak Flow Meter). Measurements were made 12 times with 2 different tube pressures with the highest error of 4.21% and the lowest of 0.50%. This module has also been tested on 11 patients who have differences in age, sex, and height. Data retrieval is done using a module and a comparison tool (Peak Flow Meter). Measurements were carried out in accordance with the SOP for checking peak flow meters, using the same module and comparator, 3 times in each data collection. The data obtained with the highest error value of 3.08% and the lowest error of 0.22%.

In her previous research, Anisa developed a peak flow meter which is equipped with inspection and storage results. This Peak Flow Meter is also equipped with display facilities and data storage using an SD Card, but the device cannot display graphic data of the examination results and cannot print the results of the examination directly. This study shows that this module can be used to monitor the patient's peak expiratory rate, which has been developed and equipped with a data storage system, print results, and examination results. This module consists of the MPX5100GP pressure sensor which is used to determine the respiratory pressure exhaled by the patient through the mouthpiece. The sensor output is filtered with a capacitor which is also useful as a decoupling circuit for the input voltage. The output of the filtered sensor is then converted into a stream using the Arduino microcontroller. Before the sensor gets input from the mouthpiece that the patient blows, the patient enters data in the form of height, age, and gender. The data will then enter the microcontroller to calculate the normal limits of the patient's PEF according to the data that has been input. This module is also equipped with an SD Card module which is used as a place for the SD Card as a data storage medium for the measurement results in this module. In addition, there is also a DS3231 RTC module to determine the time when measurements are taken.

Based on the results of this study, there are some limitations experienced and can be some factors that can be more considered. Some of the limitations in this study are the number of respondents who are only 11 people, of course, still not enough to describe the real situation, the use of pressure sensors that make several unit conversions occur to create a fairly high error value, and the module design is too large to make it difficult during inspection.

From this study, it can be concluded that MPX5100GP pressure sensor can be used to determine peak expiration value of lungs. Furthermore, this development can be used for checking PEFR values that test results can be displayed in real time on the nextion TFT, stored in a micro SD Card in txt form can be processed on PC to produce graphics and can be printed immediately because system has been equipped with a printer

V. CONCLUSION

After making and studying literature, testing modules, and collecting data, the authors can conclude as follows: The MPX5100GP pressure sensor can be used to determine the value of human expiration. The examination results can be seen in real time on the TFT nextion display. The data stored in the micro SD Card is stored in txt format and can be processed via Ms. Excel to generate graph data. The examination results can be printed immediately after the measurement is completed. The error value of the largest module is 4.21% and the lowest error value is 0.50%. There are several shortcomings in the results of this study, which are expected to be factors that can be considered in further research.

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ATTACHMENT

A. Schematic + Board
https://drive.google.com/file/d/1IiAaaPtX_CTRXAZ9BUT4F97WnIm0ZwNq/view

B. Listing Program
https://drive.google.com/file/d/1kTxe3HbjckXdBIcy4V-fdl1KvEhnF1WY/view?usp=sharing

C. Nextion Editor Program
https://drive.google.com/file/d/1oR3C9C2cfk9XRYRtMsrn-NOQI1YTf0JX/view?usp=sharing