

Research Article

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PC-based spirometer with flow sensor

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Corresponding author's email address handleHj.Andjar Pudji, ST, MT. : andjar.pudji@gmail.com**Abstract**

The respiratory system is a respiratory system that is used for gas exchange processes, where the respiratory system is one of the systems that plays a very important role in the body to support survival. By definition, chronic obstructive pulmonary disease (COPD) can be referred to as a progressive chronic disease of the lungs which is characterized by obstruction or obstruction of air flow which is irreversible or partially reversible and causes significant extrapulmonary consequences that contribute to the patient's severity. A spirometer is a tool used to measure and diagnose the condition of human lungs. The aim of this research is to develop previous research, namely by replacing the pressure sensor with a flow sensor and using the Visual Studio display on a PC. The design of this tool consists of an Arduino microcontroller and a flow sensor. The sensor is connected directly to the microcontroller as a voltage source and controller for the sensor's work which will then be displayed on the Nextion LCD and Visual Studio. with a Bluetooth connection connected to a PC with a Visual code display. Data collection will be connected to a calibrator tool using a Tube with 6x repetition. When making the module, use the measuring parameters FVC, FEV1, VCE and VCI. From the results of the spirometer module test with a comparison tool carried out in 10 respondents with 6 repetitions found an error of 3.3% for the FVC parameter and 10.6% for the FEV1 parameter. From the results of this study it can be concluded that the flow sensor can be used to determine the volume of the lungs. Furthermore, this development can be used to check FVC, FEV1, VCE, and VCI values, the results of which can be displayed in real time on the Nextion LCD or displayed in Visual Studio to produce numbers and graphs.

Keywords*spirometer, ppok, flowsensor, visualbasic, nection,fvc, fev1, vci, vce***Specifications table**

Hardware name	PC-based spirometer with flow sensor
Subject area	- Electronics and Microcontroller system - Diagnostic Engineering
Hardware type	- Measuring physical properties and in-lab sensors - Field measurements and sensors - Electrical engineering and computer science - Mechanical engineering and materials science - Mechatronic engineering
Closest commercial analog	This hardware provide PC-based spirometer
Open source license	https://creativecommons.org/licenses/by-sa/4.0/
Cost of hardware	26.75 US\$
Source file repository	DOI 10.17605/OSF.IO/PQGR5

1. Hardware in context

The respiratory system is a respiratory system that is used for gas exchange processes, where the respiratory system is one of the systems that plays a very important role in the body to support survival. The respiratory system is formed by several structures, all of these structures are involved in the process of external respiration, namely the exchange of oxygen between the atmosphere and blood and the exchange of carbon dioxide between the blood and the atmosphere, apart from that there is also internal respiration, namely the process of gas exchange between circulating blood and tissue cells, where the respiratory system This internal process occurs in all body systems [1]. The presence of oxygen is one of the gas components and a vital element in the metabolic process and to maintain the survival of all body cells.[2] Oxygen is a chemical element that is needed by humans as the main ingredient for expiration and inspiration. Inspiration is the process of bringing oxygen from the air into the body organism's body, while expiration is the process of expelling[3]. Inspiration or breathing can be interpreted as the process of inhaling oxygen (O₂) from the air and expelling (CO₂) carbon dioxide or exhalation and water vapor as residue from the oxidation of food substances [4]. COPD is a trigger for morbidity and deaths that impact the problem Public health. [5]Employment, smoking, and history respiratory system disease percentage more than 50% and very large may be a triggering factor occurrence of COPD[6].Estimated 13 million deaths around the world each year due to environmental causes. This is a timely reminder of the need to understand the wide range of factors that contribute to the global burden of lung diseases such as chronic obstructive pulmonary disease (COPD) [7]. Chronic obstructive pulmonary disease (COPD) is a major global health problem due to 27 its high prevalence (about 10% of the adult population), raising incidence (related in 28 part to the ageing of the population) and very significant associated personal, social and 29 economic costs[8]. By definition, chronic obstructive pulmonary disease (COPD) can be referred to as a progressive chronic disease of the lungs which is characterized by obstruction or blockage of air flow which is irreversible or partially reversible and causes significant extrapulmonary consequences which contribute to the severity of the patient. COPD is usually associated with an inflammatory response. abnormal lung exposure to harmful particles in the air. COPD is a multicomponent disease characterized by mucus hypersecretion, airway narrowing, and damage to the lung alveoli. This disease can be a condition related to chronic bronchitis, emphysema, or a combination of both. 3 In COPD, chronic bronchitis and emphysema are often found together, even though they have different processes. However, according to PDPI 2010, chronic bronchitis and emphysema are not included in the definition of COPD, because chronic bronchitis is a clinical diagnosis, while emphysema is a pathological diagnosis. 1,3,4 Chronic bronchitis is a respiratory tract disorder characterized by a chronic cough that produces phlegm for at least 3 months of the year, at least two consecutive years and not caused by other diseases. Emphysema is an anatomical lung disorder characterized by widening of the distal air spaces in the terminal bronchioles, accompanied by damage to the alveolar walls. 1,4 It is not uncommon for chronic bronchitis sufferers to also show signs of emphysema, including severe persistent asthma sufferers with airway obstruction that is not completely reversible. , and meet COPD criteria[9]. Acute Respiratory Infection (ISPA) is diseases that can attack one or more parts of the respiratory tract, from the nose (upper tract) to the alveoli (lower tract) including adnexal tissues such as sinuses, middle ear cavity, and pleura.[10]

This health information can be taken into consideration, to design a reliable real-time monitoring system has attracted much attention of researchers' interest. Data that describes the occurrence of inspiration and expiration that takes place in human lungs is collected using sensors that can be connected to communication devices such as PCs. This is intended to provide health service care by users. Transmission of health information can be done via cable and wireless. From a systems point of view, humans are slow objects, prone to errors, inefficient data conveyors and have limitations in terms of quality and quantity, and even have the possibility of reducing the authenticity of the data. The increasing number of work demands and human limitations is what becomes an obstacle for a system to run well [11]. Telespirometry in subjects attending their clinics who had risk factors, persistent respiratory symptoms, or a previous diagnosis of asthma or COPD [12].Telespirometry is a telemedicine application that aims to support monitoring, and ultimately improve, the quality of spirometry tests carried out in primary care practices. In telespirometry, up to 10% of spirometry tests are sent randomly to pulmonologists who then provide comments regarding the quality of the spirometry tests. Complementary to this telepulmonology is a telemedicine application where general practitioners are supported by pulmonary specialists in interpreting spirometry tests. Telepulmonology also plays a role in reducing the number of physical referrals of patients to pulmonologists [13]. Spirometer has demonstrated consistency that is similar to that of traditional pulmonary function equipment in the determination of various parameters.[14] Therefore, a system is needed to monitor the patient's condition in real time which can be reviewed via a PC using wireless monitoring which aims to ensure that there is no transmission of disease between the operator and the user. This is intended to make it easier for health workers to monitor the patient's physical condition directly [15].

Based on a literature search from several studies conducted in 2015, Ahmad Zainuddin, et al conducted research to utilize the MPX5100DP pressure sensor as a transducer. The voltage issued by the sensor is converted by the microcontroller ADC. The resulting data is a discharge value as a lung volume value which is then displayed on the PC. If there are researchers who continue this research, they are advised to design tools that are simple or portable and can store data.

The drawback of this research is that it cannot display graphs automatically when data is being collected. [16] In 2016, Wahyu Teja Kusuma, et al successfully conducted research by building an application to measure the health of human lung function using a microphone on a smartphone. Apart from that, this module does not yet appear on a PC and still uses the microphone API as an input tap, and is not equipped with graphics on its display [17]. Lia Andriani, et al have conducted research on portable spirometer devices. This study used a disposable funnel. This mouthpiece is positioned in the mouth to blow air. An instrumentation amplifier is built based on IC358 to amplify the results of the MPX5100DP sensor. The Arduino Uno microcontroller is used to process data generated from the amplifier and the voltage data will be converted into volume units. Lia Andriani's portable spirometer measures FVC and FEV1 parameters and the measurement results will be displayed on the LCD. However, this research has a drawback, namely that the tool has an imperfect funnel design [18]. In 2020, Lizarazu conducted research on a portable spirometer measuring the parameters VC, FVC and FEV1. The results of measurements by the MPX7002V pressure sensor will later be displayed on the Nextion TFT LCD and stored on the SD Card in the form of values that have been converted into volume units by the microcontroller ADC. However, this research has a drawback, namely that it does not display on a PC and still uses a sensor in the form of a pressure sensor module [19].

Based on the literature search that I found, previous research mostly used pressure sensors of several types and still used one method, namely exhalation. Therefore, here I want to carry out development by adopting the title "SPIROMETER WITH PC-BASED FLOW SENSOR" from that title, I want to overcome the spread between operators and users by using the HC-08 bluetooth module, so that transmission cannot occur, which in the measurement This requires knowing the lung volume levels in 2 modes, namely expiration and inspiration. So I will take data through a module that I created with 2 methods of inspiration and expiration, along with the measuring parameters FVC and FEV1. This research aims to make it easier for health workers or doctors to take further action for patients.

In this research, I used a flow meter sensor equipped with 2 methods, namely Inspiration and Expiration. These 2 methods are equipped with FVC and FEV measuring parameters. After taking parameter data on the patient, the final results are in the form of graphs and volume values (mL) which will be displayed on a PC using a media platform, namely Microsoft Visual Basic using Wireless Media connected to the Module. which is controlled with the Arduino Mega Mini Pro microcontroller



Fig.1. Visible in the module

The picture above is the entire series of the spirometer module that has been made. The circuit gets supply from the battery. The sensor next to the potentiometer is a flow sensor which will produce an output in the form of liters. The sensor is connected to pin D2, which aims to process sensor data. Apart from pin D2, the flow sensor is also connected to pin 5v and GND. Then there is LCD NEXTION as a display output which is connected to pins D15 and D16 as serial communication pins on RX3 and TX3 on the Arduino mega mini pro, and esp 32 on pins D16 and D17 as serial communication pins on RX2 and TX32 esp 32 on Arduino mega mini pro for data reception.

2. Hardware description

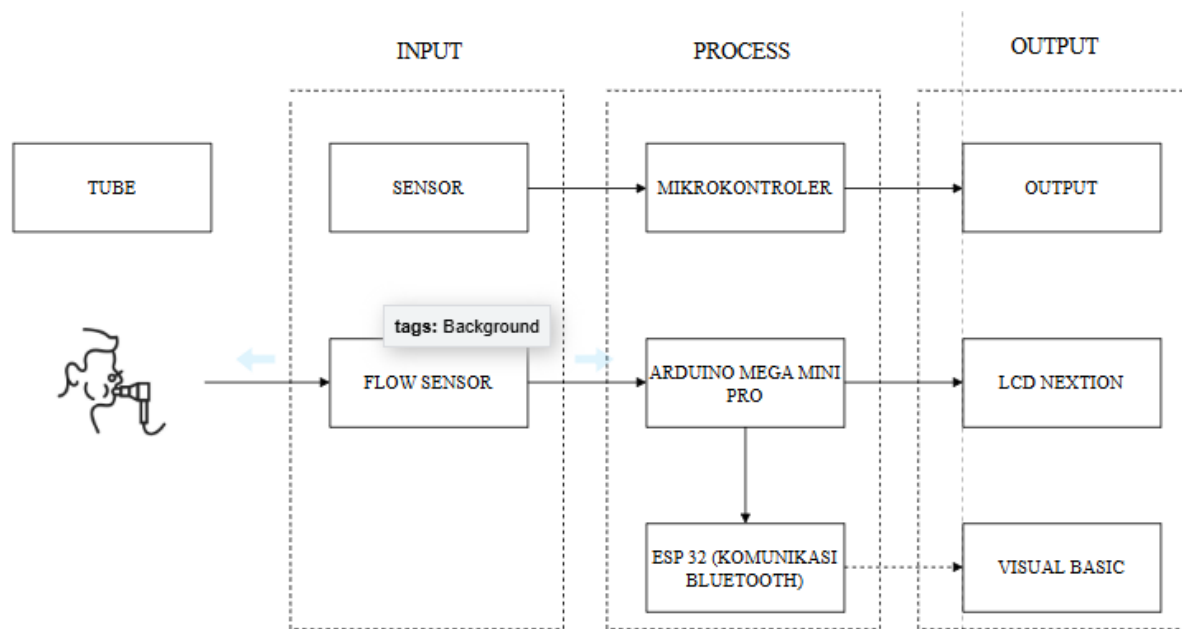


Fig. 2. The diagram block of the *PC-based spirometer with flow sensor*

This research uses a mouthpiece as the air input that is expelled from the respondent. The air flow will be received and read by the flow sensor. Which produces ml/P output on the Arduino Mega Mini Pro. The Arduino Mega Mini Pro microcontroller will send processed data which will be displayed on the Nexion LCD and PC and via the microcontroller's TX and RX pins. The process continues on Bluetooth which uses ESP 32 as a transmitter to send data. Then, it is received on the PC's Bluetooth as a receiver. The results of lung volume measurements will be displayed on the PC via the VB.net application in the form of values and graphs, where the values will be converted into graphic form.

2.1. Spirometer hardware

Shows the results of the module design that has been created. On the outside of the front there is a Nexion LCD screen and a tube to position the mouthpiece. Meanwhile, on the external display there is a Nexion LCD as a medium for displaying measurement results on the module tool. Apart from that, there are also 2 sensor input and output holes connected to the mouthpiece for measuring the turbine flow sensor, the left part is for air input or a funnel that is placed in the patient's or respondent's mouth, while the right part is only for air output. A disposable mouthpiece will be added to the input funnel when measurements are taken. Then for the inside there is a series of Arduino Pro Mini and ESP32 microcontrollers, as well as a flow turbine sensor for measuring lung function.



a) 3D print tube and flow sensor design



b) Visible in the module



c) Side view with switch



d) Top view with LCD display

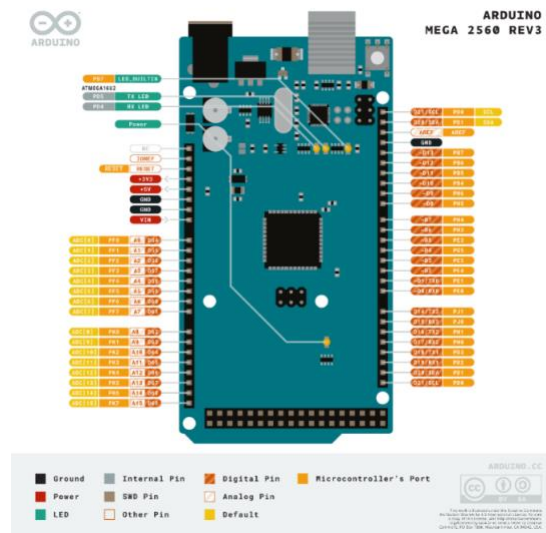
Fig. 3.

2.2. Hardware Circuit

This research uses 1 sensor (OF05ZAT) and 2 hardware devices namely Arduino mega 2560 pro mini and ESP 32. This circuit uses the OF05ZAT sensor with simple structure due to the elliptic gears employed as a measuring principle that can be used to measure the micro flow[20]. This sensor has the advantage of being high reproducibility of results and quite practical measurement accuracy[21]. Arduino Mega Mini Pro microcontroller to transmit processed data which will be displayed on the Nextion LCD and PC and via the TX and RX pins of the microcontroller. ESP 32 as a transmitter to send data. Then, it is received on the PC's Bluetooth as a receiver. The Arduino Mega 2560 Pro Mini serves as a data processing microcontroller responsible for handling the data received from the sensor reading. [22]. Arduino Mega 2560 presented in Fig. 9 is a microcontroller that uses ATmega2560 microcontroller ic. Arduino Mega 2560 has 54 digital I / O pins with 16 [23]. (of which 15 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

Table 1**Summary of Arduino Mega Mini Pro Specification**

Items	Specification
Microcontroller	ATmega2560
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	54 (of which 15 provide PWM output)
Analog Input Pins	16
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	256 KB of which 8 KB used by bootloader
SRAM	8 KB
EEPROM	4 KB
Clock Speed	16 MHz
LED BUILTIN	13
Length	101.52 mm
Width	53.3 mm
Weight	37 g



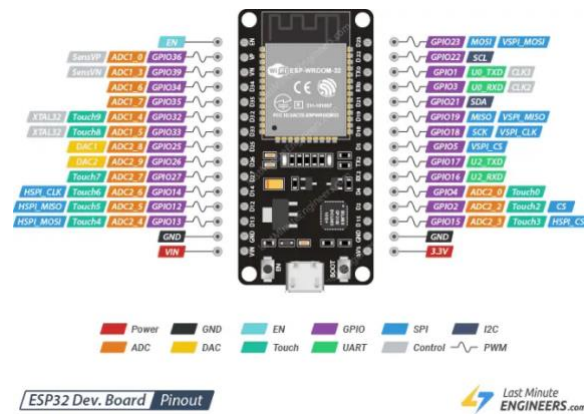


Fig. 5. ESP32-WROOM-32 Pinout

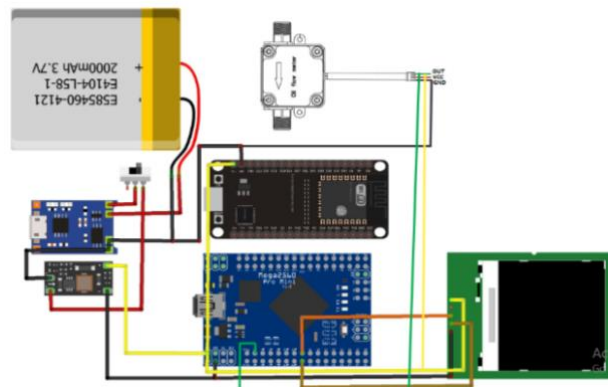


Fig. 6. overall circuit

The flow sensor circuit uses the OF05ZAT flow sensor type. The output from this flow sensor becomes input to the microcontroller using the Arduino Mega Mini Pro microcontroller on pin D2. The flow sensor is also connected to pin 5v and GND. Then there is LCD NEXTION as a display output which is connected to pins D15 and D16 as serial communication pins on RX3 and TX3 on the Arduino mega mini pro, and esp 32 on pins D16 and D17 as serial communication pins on RX2 and TX32 esp 32 on Arduino mega mini pro for data reception.

2.3. Arduino Program

This tool defines parameter measurements, sends data to the PC, sends data to the Nextion LCD, on a module designed using the Arduino program. The Arduino program functions to process the output from the circuit and then send it using Bluetooth communication. This module also has storage which is stored in the form of a database on the Visual Studio Code Platform. The data in this format presents examination time, name, age, height, gender, measuring parameter values, FVC, FEV1, VCI, VCE, and graphs. This display was created using the Visual Studio Code platform. Visual Studio Code is a platform for displaying the results of a design which provides facilities for displaying the results in the form of numbers and graphs that are needed in the creation of this research module using the drag and drop block programming concept. This application is equipped with a database using My SQL.

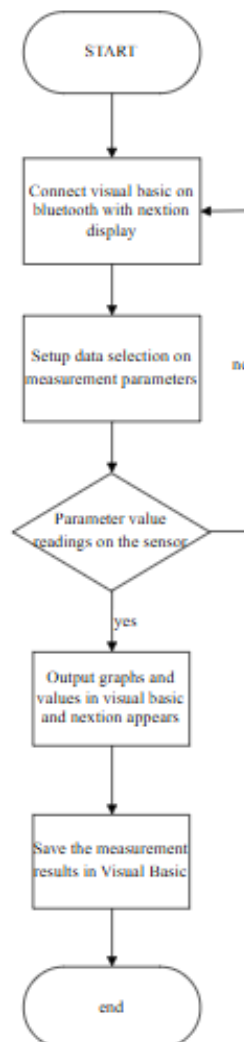


Fig. 7. Flowchart

In this flow diagram, when the tool is turned on, the system will initialize, continue with the connection to the PC's Bluetooth via Visual Basic and will connect to the Nextion LCD, then select the measurement mode in which the data will be taken and will continue to send via Bluetooth. If the Bluetooth receiver and transmitter are not connected, it will return to the initialization process. If Bluetooth is connected, the data that has been received will be read on the PC via Bluetooth with the Visual Basic application display and Nextion LCD and the results can be saved in Visual Basic.

2.4. Bluetooth media

To minimize transmission between the operator and the patient, this tool is made using Bluetooth media. The process of sending data via Bluetooth uses ESP 32 as transmitter. Then, it is received on the PC's Bluetooth as a receiver. The results of lung volume measurements will be displayed on the PC via the VB.net application in the form of values and graphs. In this measurement, lung volume levels must be known in 2 modes, namely expiration and inspiration, along with the measuring parameters FVC and FEV1. This research aims to make it easier for health workers or doctors to take further action for patients.

2.5. Cost

Commercial Spirometer products are expensive at 346.77 USD and not all of them are PC-based. However, this design has a low cost of 26.75 USD for one spirometer product. In addition, this design is open source so that other researchers can develop it with other features and improvements.

2.6. Summary

1. The purpose of this PC-based spirometer tool is to carry out lung examinations using a flow sensor and make it easier for users to monitor and prevent transmission between users and patients.

2. This tool was made using Bluetooth media to minimize transmission between the operator and the patient.
3. This tool also has storage which is stored in the form of a database on the Visual Studio Code Platform.
4. The data displayed includes examination time, name, age, height, gender, measuring parameter values, FVC, FEV1, VCI, VCE, and graphs

3. Design files summary

3.1. Design file

This section outlines the resulting design files, which comprise both the hardware design (circuit design, schematic and printed circuit board (PCB)) and the firmware to operate the tool. The firmware for reading the flowrate sensor is also presented in Table 3.

Table 3

Design file summary of PC-based spirometer with flow sensor

Design file name	File type	Open source license	Location of the file
Spirometer.pdf	circuit, pdf	CC BY-SA 4.0	DOI 10.17605/OSF.IO/PQGR5
Spirometer.sch	schematic, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/PQGR5
Spirometer.brd	board, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/PQGR5
Sensor.ino	firmware, Arduino	CC BY-SA 4.0	DOI 10.17605/OSF.IO/PQGR5
Nextion.ino	firmware, Arduino	CC BY-SA 4.0	DOI 10.17605/OSF.IO/PQGR5

3.2. Schematic and Board

The spirometer was designed using the Eagle application programme (6.3.0, free version for Windows, CadSoft Computer GmbH, Germany). The schematic file contains the flowsensor circuit connected to the D2 pin of the Arduino Mega Mini Pro, ESP32 and LCD Nextion communicating serially with the Arduino Mega Mini Pro using RX-TX.

3.3. Firmware

The spirometer firmware was developed using the Arduino application programme. Table 3 shows two firmwares, namely Sensor and Nextion. The sensor firmware is programmed on the Arduino Mega Mini Pro to read data from the flowrate sensor. Furthermore, the sensor reading results are sent using the function using RX-TX serial communication to the Nextion LCD for display and sent to the ESP32 which will be forwarded to the PC.

4. Bill of materials summary

Table 4

Bill of materials of a hand exoskeleton

Designator	Component	Number	Cost per unit (USD)	Total cost (USD)	Source of materials	Material type
U1	Arduino Mega Mini Pro	1	10,92	10,92	https://www.aliexpress.com/item/1005007044509990.html	Semi-conductor
U2	ESP32-WROOM-32	1	3,64	3,64	https://www.aliexpress.com/item/1005006687578028.html	semi-conductor

NEXTION	Nextion Intelligent HMI Display	1	40,64	40,64	https://www.aliexpress.com/item/1005006619737286.html	semi-conductor
SENSOR	Flowsensor	1	10,31	10,31	https://jogjarobotika.com/flow-meter/2707-high-concentration-liquid-flow-sensor-aichi-of05zat-12-inch.html	Metal and plastic
MOD1	Tp4056 Module	1	0,36	0,36	https://www.aliexpress.com/item/4001196670805.html	semi-conductor
MOD2	MT3608 step up DC-DC module	1	1,52	1,52	https://www.aliexpress.com/item/4001123244040.html	semi-conductor

5. Build instructions

5.1 Firmware Design

The firmware is designed using Arduino and Visual Basic.NET software. In this case, the Bluetooth Low Energy feature of ESP32 is used to send data to the PC. The user must perform Bluetooth pairing between ESP32 and PC, so that the data can be forwarded by Visual Basic.NET and displayed to the user.

5.2. Hardware Circuit

In the spirometer box there is a sensor along with a microcontroller. on the front side of the tool there is a Nextion Display. while the right side is the input of the flowsensor and the left side is the flowsensor output. The flowsensor module is connected to the Arduino Mega Mini Pro digital pin. The Esp32 and Nextion Dsisplay modules are connected to the RX2-TX2 and RX3-TX3 pins respectively on the Arduino Mega Mini Pro. all components on the box are mounted on the top of the PCB. The switch is used to switch the device on and off. when the switch is in the ON position, all modules get power from the 18650 battery.

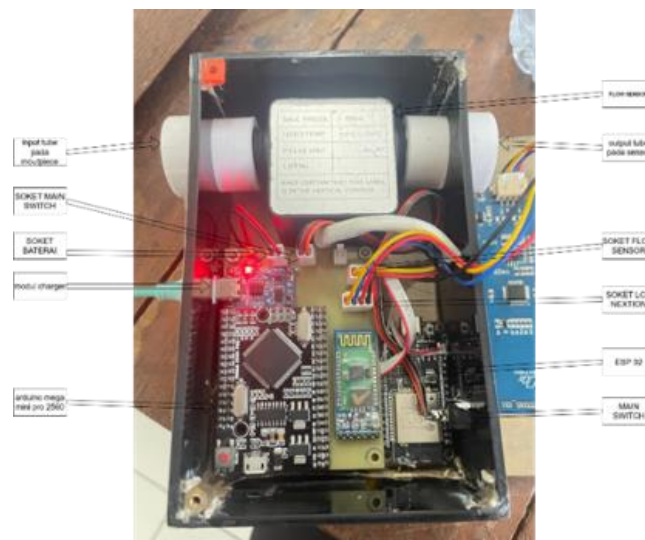


Fig. 8. Hardware Circuit

6. Operation instructions

1. The patient's body position is relaxed
2. Inhale as much air as possible then exhale as long as possible until the air runs out in the mouthpiece.
3. Wait until the display on the Nextion screen and the connected PC indicates that measurements can be taken.
4. Then, take measurements on the tool that is installed on the mouthpiece connected to the sensor.
5. Next, inhale as much air as possible and then exhale as quickly as possible through the mouthpiece.
6. Wait until the measurement numbers are generated and the graph has been generated and it will be sent to the PC on the Visual Studio platform.

7. Validation and characterization

The following **Table 5** is the result of test point measurements on the module using a multimeter showing the voltage and air flow values measured at various test points. These values can be used to analyze module performance and to identify potential problems.

Table 5

measurement (V)	Flow (L/sec)
0	without blowing
0.4	0.8
2.4	2.3
2.5	2.6
2.5	3.1

Data collection for the tool was carried out on the Hans Rudolph 5530 Syringe Calibrator at PT. Surya Medikal Servis is a calibration company in Surabaya. Data collection will be connected to a calibrator using a Tube and will be carried out with 6 repetitions. The following are the results of the data measurements obtained:

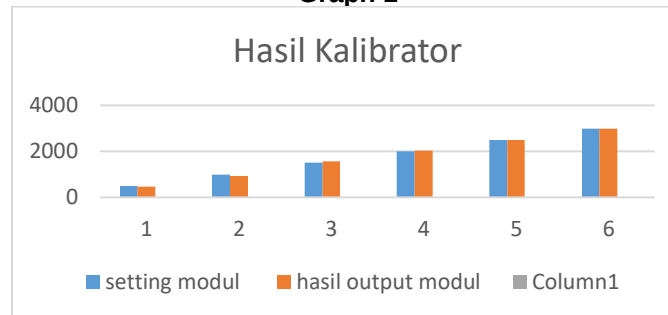
Table 6

Experiment	Calibrator	Module
1	500ML	470ML
2	1000ML	940ML

3	1500ML	1570ML
4	2000ML	2040ML
5	2500ML	2510ML
6	3000ML	2980ML

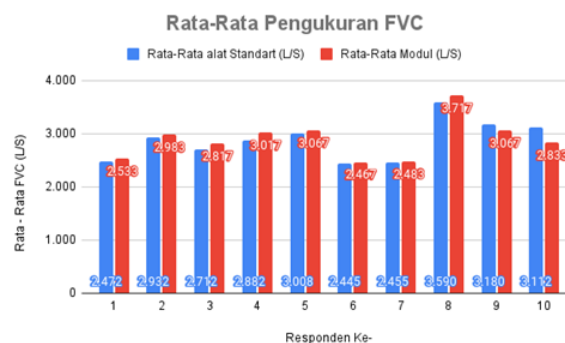
It can be seen in the table above that there is a small average error value which is a comparison of the module and calibrator tool. A small error value shows that the tube size is suitable for use in this spirometry module. The results from the tool show the module volume value that corresponds to the tool settings on the calibrator tool.

Graph 1



Based on this graph **graph 1**, we can see the output value of the module and the value of the calibrator that uses the right tube. Data collection experiments were carried out 6x. The stability of the module and calibrator output values looks stable when using a tube, which means the tube size fits the module. The following **graph 2** shows that the average FVC value on the module is generally higher than the average FVC value on the standard device. This shows that the module has better accuracy than standard tools in measuring FVC. However, keep in mind that this graph only shows the average of FVC measurements in 10 patients. In measuring the FVC parameters, the highest FVC value on the module was in patient 8 with an average of 3,717 L/s, while the FVC parameter on the standard device with the highest FVC value was in patient 8 with an average of 3,590 L/s. The lowest average value in the tool module was found in patient data collection 6, namely 2.467 L/s. Likewise, the lowest average value on the standard tool was 2.445 L/s in patient 6.

Graph 2



The following **Table 7** is the result of measurements between modules and standard tools. The data was collected on 10 respondents with 6 measurements on each respondent. From the results shown in the table above, it can be concluded that the measurements carried out on 10 respondents had different errors for each respondent, namely between 0.9% to 8.9% in the module with standard tools with the largest error obtained being 8.9% for the respondent. 10. And the smallest error was 0.9% for respondent 6. The measurement results between the standard tool and the module with the overall error value between the module and the comparison tool are $\pm 3.3\%$, which indicates that the FVC on the tool module when compared with the comparison tool results are quite good.

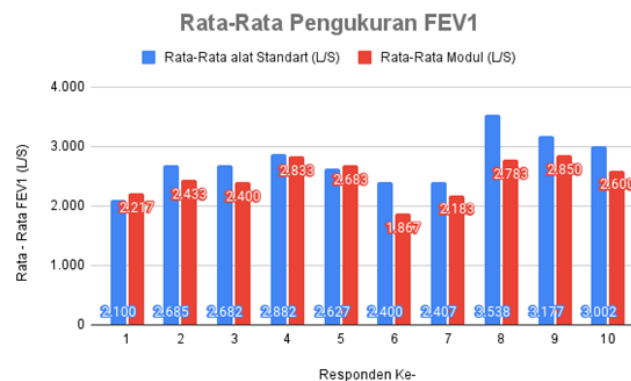
Table 7

FVC

Respondent	Average Standard Equipment (L/S)	Module Average (L/S)	SD (L/S)	Error (%)
1	2.472	2.533	103	2.5
2	2.932	2.983	248	1.8
3	2.712	2.817	685	3.9
4	2.882	3.017	271	4.7
5	3.008	3.067	163	1.9
6	2.445	2.467	151	0.9
7	2.455	2.483	2.228	1.2
8	3.590	3.717	331	3.5
9	3.180	3.067	197	3.6
10	3.112	2.833	339	8.9
OVERALL			472	3.3

The **graph 3** below shows that the average FEV1 value on the module is generally higher than the average FEV1 value on the standard device. This shows that the module has LESS WELL accuracy than standard tools in measuring LESS WELL. However, keep in mind that this graph only shows the average of FEV1 measurements in 10 patients. In measuring the FEV1 parameter, the highest FEV1 value on the module was in patient 9 with an average of 2,850 L/s, while the FVC parameter on the standard tool with the highest FEV1 value was in patient 8 with an average of 3,538 L/s. The lowest average value on the module was in patient 7, namely 2,183 L/s and on the standard device, namely 2,100 L/s in patient 1.

graph 3



The following **Table 8** is the results of measurements between modules and standard tools. The data was collected on 10 respondents with 6 measurements on each respondent. From the results shown in the table above, it can be concluded that the measurements carried out on 10 respondents had different errors for each respondent, namely between 1.7% to 22.2% in the module with standard tools with the largest error obtained being 22.2% for respondent 6. And the smallest error was 1.7% for respondent 4. The measurement results between the standard tool and the module with the overall error value between the module and the comparison tool are $\pm 10.6\%$, which indicates that the results of the FVC on the tool module when compared with the comparison tool are not good.

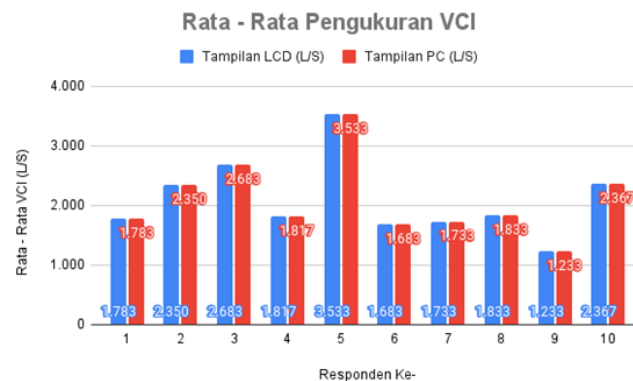
Table 8

FEV1

Respondent	Average Standard Equipment (L/S)	Module Average (L/S)	SD (L/S)	Error (%)
1	2.100	2.217	293	5.6
2	2.685	2.433	163	9.4
3	2.682	2.400	469	10.5
4	2.882	2.833	163	1.7
5	2.627	2.683	214	2.2
6	2.400	1.867	250	22.2
7	2.407	2.183	293	9.3
8	3.538	2.783	232	21.3
9	3.177	2.850	243	10.3
10	3.002	2.600	283	13.4
OVERALL			260	10.6

The following **graph 4** shows that the average VCI value on the module is generally higher than the average VCI value on the standard device. This shows that the module has GOOD accuracy than standard tools in measuring GOOD. However, keep in mind that this graph only shows the average VCI measurements in 10 patients. In measuring the VCI parameters, the highest VCI value on the LCD display was in patient 5 with an average of 3,533 L/s, while the VCI parameter on the PC display with the highest VCI value was in patient 5 with an average of 3,533 L/s. Meanwhile, the lowest average value on the LCD display was found in patient 9, namely 1,233 L/s, as well as the display on the PC, found in patient 9, namely 1,233 L/s.

graph 4



The following **Table 9** is a measurement of the VCI parameters showing the average results displayed on the Nextion, and the data displayed on the PC. Of the 10 respondents, data was collected 6 times for each respondent. Then, from the data obtained, the SD value was calculated between the displays on Nextion and PC, and the data displayed on PC and Nextion for 10 respondents had different SD values for each respondent, namely between 175 to 454 in the module with display on Nextion and the PC with the largest SD obtained was 454 for respondent 3. And the smallest error was 175 for respondent 5.

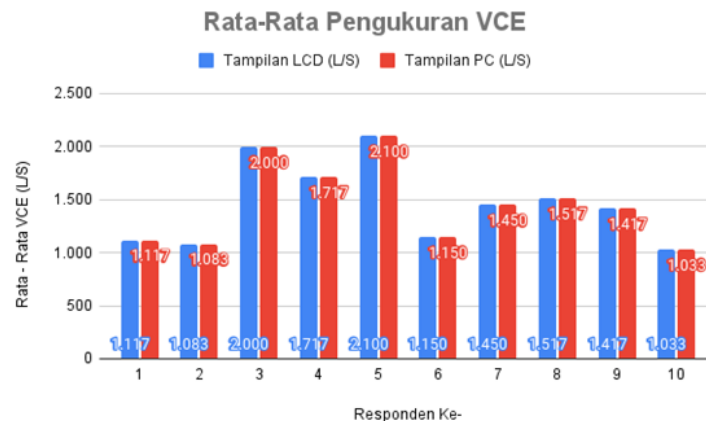
Table 9

VCI				
Respondent	LCD Display (L/S)	PC Display (L/S)	SD (L/S)	Error (%)
1	1.783	1.783	279	0

2	2.350	2.350	187	0
3	2.683	2.683	454	0
4	1.817	1.817	232	0
5	3.533	3.533	175	0
6	1.683	1.683	360	0
7	1.733	1.733	403	0
8	1.833	1.833	273	0
9	1.233	1.233	207	0
10	2.367	2.367	356	0
OVERALL			0.29	0

This **graph 5** shows that the average VCE value on the module is generally higher than the average VCE value on the standard tool. This shows that the module has GOOD accuracy than standard tools in measuring GOOD. However, keep in mind that this graph only shows the average of VCE measurements in 10 patients. In measuring the VCE parameters, the highest VCE value on the LCD display was in patient 5 with an average of 2,100 L/s, while the VCE parameter on the PC display with the highest VCE value was in patient 5 with an average of 2,100 L/s. Meanwhile, the lowest average value on the LCD display was found in patient 10, namely 1,033 L/s, as well as the display on the PC, found in patient 10, namely 1,033 L/s.

graph 5



The following **Table 12** is a measurement of the VCI parameters showing the average results displayed on the Nextion, and the data displayed on the PC. Of the 10 respondents, data was collected 6 times for each respondent. Then, from the data obtained, the SD value was calculated between the displays on Nextion and PC, and the data displayed on PC and Nextion for 10 respondents had different SD values for each respondent, namely between 133 to 376 in the module with display on Nextion and the PC with the largest SD obtained was 376 for respondent 9. And the smallest error was 133 for respondent 8. The measurement results between the standard tool and the module with the overall error value between the module and the comparison tool are $\pm 0.23\%$, which indicates that the VCE parameters on the tool module when compared with the comparison tool, the results are good.

Table 12

VCE				
Respondent	LCD Display (L/S)	PC Display (L/S)	SD (L/S)	Error (%)
1	1.117	1.117	172	0

2	1.083	1.083	160	0
3	2.000	2.000	297	0
4	1.717	1.717	160	0
5	2.100	2.100	179	0
6	1.150	1.150	259	0
7	1.450	1.450	243	0
8	1.517	1.517	133	0
9	1.417	1.417	376	0
10	1.033	1.033	294	0
OVERALL			0.23	0

8. Conclusion

The PC-based spirometer tool was created to carry out lung examinations using an air flow sensor, as well as making it easier for users to monitor and prevent transmission between the operator and the patient. The measurement results from the PC-based spirometer module were compared with the Hans Rudolph 5530 Syringe Calibrator. From the test results of the spirometer module with a comparison device carried out on 10 patient respondents by taking data 6 times, there was an error of 3.3% for the FVC and 10.6% on the FEV1 parameter. For the VCI parameters, there is an error of 0.29% and for the VCE parameters there is an error of 0.23%..

Ethics statements

The author confirmed that informed consent was obtained from the subjects. This research has passed the ethical examination conducted by Health Research Ethics Committee Poltekkes Kemenkes Surabaya, Indonesia, No.EA/1245/KEPK-Poltekkes_Sby/V/2022

Credit author statement

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Declaration of interests

The authors declare that there is no conflict of interest.

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