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Arduino ATMega328 Portable Spirometer using Gas Pressure Sensor For FVC and FEV1 Measurement

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Abstract—Extreme climate change and air pollution caused by dust, smoke, vehicle exhaust gases, and industry can increase the chances of contracting various infectious diseases caused by viruses, especially respiratory infections. Lung volume measurements obtained from the air that is inhaled and exhaled by someone can help doctors diagnose abnormalities in the lungs. The purpose of this study was to develop an affordable pulmonary function measurement system, which is a spirometer. The mainboard consists of a non-inverting amplifier, Arduino microcontroller, LCD and SD Card memory. FVC and FEV1 volume measurements are carried out when the breath blew through the MPX5100DP gas pressure sensor. The sensor's output is a voltage, which is converted to a volume unit using the venturi meter method. The SD card memory is used to store data. The results of measurement data on respondents with a spirometer comparison device then there is an FVC error of 0.98% 5, FEV1 3.83% and FEVI / FVC 2.50%.

Keywords— Lung volume; MPX5100DP sensor; Spirometer; Arduino Microcontroller; SD Card

I. Introduction

A spirometer is a tool used to measure how much air can be inhaled and exhaled by a person for a certain duration. This measurement is usually done to diagnose a disease that is in the lungs, namely obstruction, and restructuring. The obstructive disease is pulmonary disease having difficulty removing air from the lungs due to blockages in the respiratory tract while restrictive diseases are pulmonary diseases where the lungs are not fully filled with air, usually due to limited lung ability to expand. Some spirometer parameters used for clinical examination include vital capacity (VC), forced vital capacity (FVC) and forced expiratory volume in one second (FEV1). Two of the three parameters can be used to determine the presence or absence of abnormalities in the lung. Extreme climate change and air pollution caused by dust, smoke, vehicle exhaust gases, and industry can increase the chances of contracting various infectious diseases caused by viruses, especially respiratory infections. Disorders of respiratory infections that occur seriously for a long time can affect lung health. If lung function checks are carried out carefully from an early age, lung disease can be cured [1]. In general, the volume and capacity of the human lungs are only influenced by age, height, and gender, besides the factors of the disease and one's activities can also affect lung capacity. An athlete and construction worker or coolies have a different lung capacity than an office worker. A person who has lung disease or asthma also has a different lung capacity compared to normal people. On people who have asthma (emphysema), the diameter of the airways in their lungs narrows, so that the flow of air in and out of the lungs becomes reduced. This resulted in a decrease in lung capacity [2]. Technological developments in the current era are very fast. Some devices have used digital systems for their use, including health equipment. One example is a spirometer. Spirometer itself is used to determine the state of lung function in humans.

In 2011Alkefas H.I. Laybahas has conducted research on "PC-based Spirometers (Expirations and Inspiration)". The device still looks on a computer / PC with a windmill system. The control circuit still uses the AT89S5 IC Microcontroller. The results showed a volume measurement error value of 2.4% in volume measurement of 0.5 L (Alkefas H.I Laybahas, 2011). In 2015 Ahmad Zainudin et al. conducted a study on "Measuring Lung Volume by Utilizing Pressure Sensors". In this study utilizing a pressure sensor for measuring vital lung capacity using physical theories namely fluid flow, continuity equation, Bernoulli equation, and venturi meter. The data from the volume measurements show LCD which are then compared with the T.K type spirometer. K 11510 Vital belongs to the SSFC Laboratory of the Faculty of Sport Sciences, State University of Surabaya and obtained the highest difference of 0.24 L [3]. In 2016 Wahyu Teja Kusuma et al. conducted research on "Application Design for Health Measurement of Human Lung Function Using Smartphone Microphone". This research utilized Smartphone media because it has Microphone API technology which is used to capture input in the form of user breathe sound recordings. The results of the measurements are compared to the original spirometer. In the results of the study, there is noise due to user sound factors or environmental conditions. [4]. In 2017 Kemalasari et al. conducted research on "Non-Invasive Spirometer with Piezoelectric Sensor to Detect Lung Health". In this study using a piezoelectric sensor placed on the chest so that changes in chest movement while breathing can be detected and

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measured by the sensor. Because the output of the sensor is small, it is carried out by amplifier circuits, low pass filters, notch filters, clampers and microcontroller AVR ATMega 32 as well as LCD to display measuring results accompanied by storage on the SD card. The results of the measurements show that the percentage of the success of the tool is 95.70%[1].

Based on the identification of the above problems, the author intends to make **"Design of Portable Spirometers to Measure the Health of Lung Functions (FVC and FEV1)".** In this study utilizing MPX5100DP pressure sensors for FVC and FEV1 measuring devices based on ATMega328 microcontroller**.** Volume measurement results and lung health conditions will be displayed on the LCD automatically. The comparator module used is real spirometer.

II. MATERIALS AND METHODS

A. Experimental Setup

This study used six normal subjects with age criteria ranging from 20-40 years and height between 150 to 172 cm. Subjects were taken randomly and collection data were repeated 6 times.

1) Materials and Tool

This study uses a disposable mouthpiece. This Mouthpiece is positioned in the mouth to blow air. An instrumentation amplifier is built based on IC358 for amplified from MPX5100DP sensor results. Arduino Uno microcontroller is used to process data generated from amplifiers and voltage data will be changed to volume units. The results of the measurements appear LCD. Memory the SD card is used to store volume measurement data. A spirometer is used to compare modules.

2) Experiment

In this study, after the design is complete, this module is tested with traceable spirometers.

B. The Diagram Block

In this study, lung volume measurement was carried out based on the blow from the respondent's mouth, then amplified using an instrumentation amplifier. The default analog to digital converter (A / D) on Arduino UNO is used to convert analog to digital data, then it will be converted to volume units with the principle of venturi meter. The results of the volume measurement data are saved to the SD card.

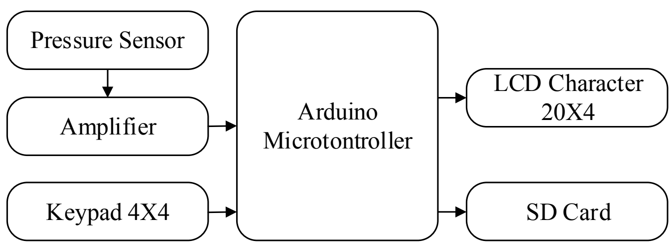

Fig. 1. The diagram block

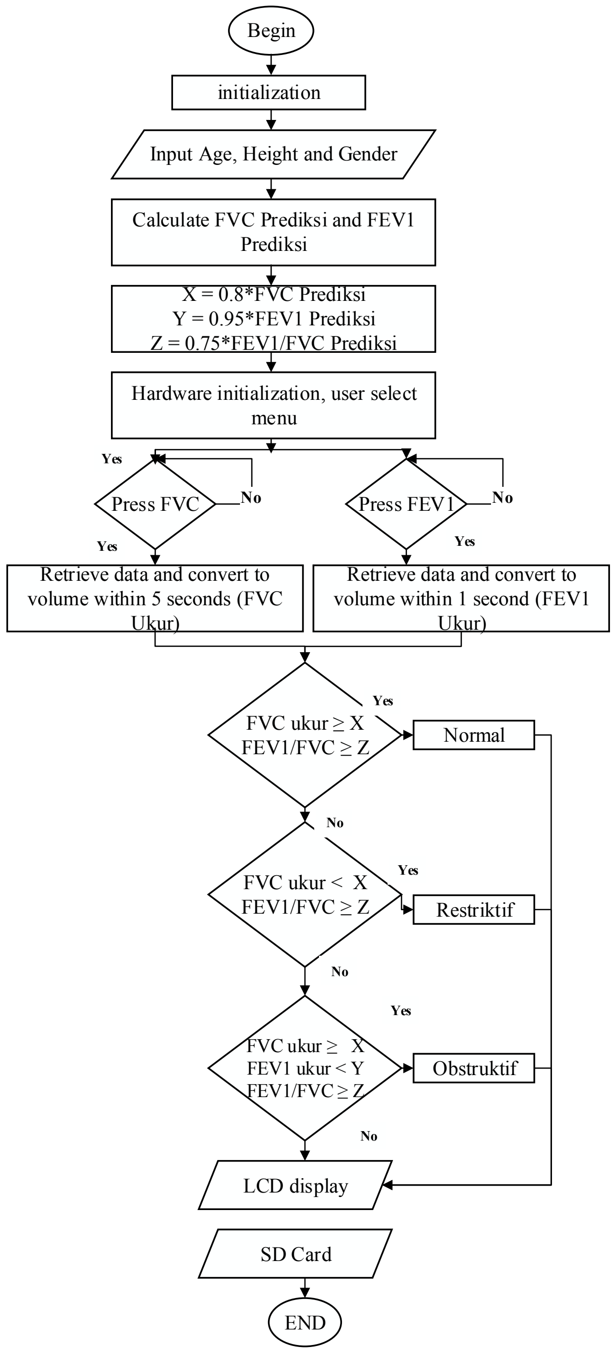

Fig. 2. The Flowchart of the Arduino Program

C. The Flowchart

The Arduino program is built on the flowchart as shown in Figure. 2. After the Arduino initialization, the program will ask for the contents of personal data such as height, gender, and age. Then the program will calculate the predicted value.

D. The Analog Circuit

An important part of this development is the analog circuit that illustrates in Fig. 3 (instrumentation amplifier), This circuit is used to amplify the results of measurements so that they can be read, Arduino. Therefore it will be ready for digital processing using Arduino.

E. Preamplifier

An instrumentation amplifier circuit as shown in Figure. 3 is a pre-amplifier for the MPX5100DP sensor amplifier that takes an important part for analog processing. This circuit consists of one OP-AMP. The overall gain is adjusted to R2 (990 ohms) and R1 (1000 ohms). Two feet of the sensor is connected to Vcc and ground, feet output 1 to the sensor are connected to a non-inverting J2 input as shown in Figure 3

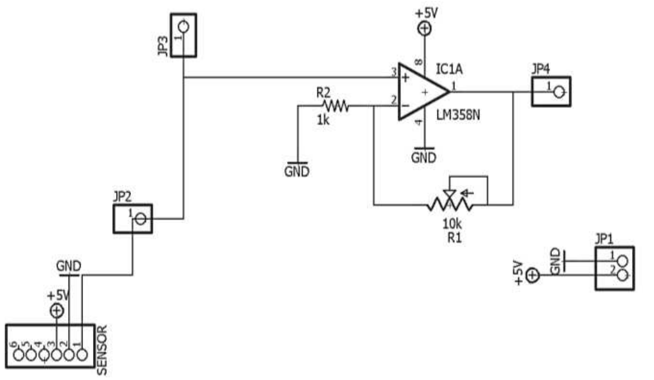

Fig. 3. Instrumentation amplifier

III. RESULTS

In this study, the module has been tested using a comparison of module measurements with traceable spirometer tools. The results show that the measurements in the module are feasible to use.

1) Test-point measurement result

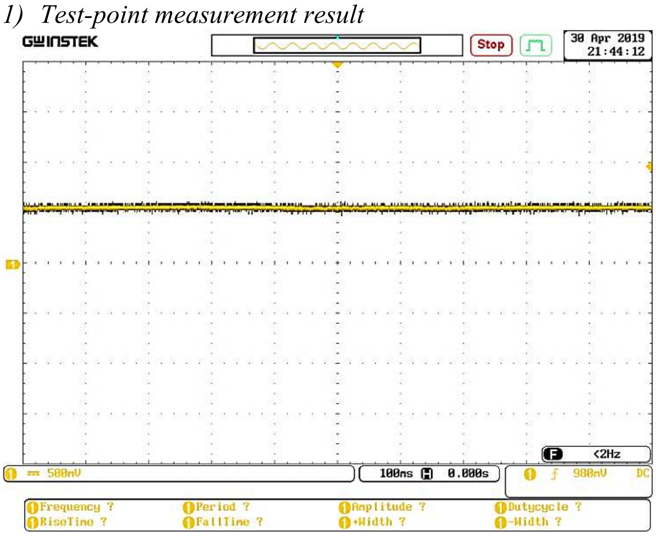

Fig. 4. MPX5100DP Sensor output result

Figure 4 shows the sensor output when measuring patient's respiratory volume once the patient's breathing.

Sensor output voltage once there was a breath:
Vout = square height x 500mV
Vout =1,0 x 500mV
Vout =0,5 V

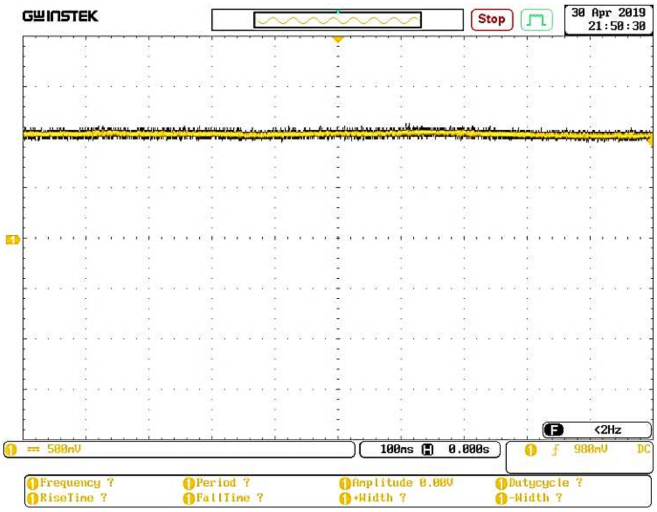

Fig. 5. The non-inverting circuit output result

Figure 4.4 shows that the gain is 2 times.
The output voltage is strong when there is a breath.
Vout = square height x 500mV
Vout = 2,0 x 500mV
Vout =1,0 V

2) The Listing Program for calculating FVC dan FEV1

In this paper, the software is only programming on Arduino, which is for programming FVC and FEV1 measurements. The listing program for Arduino is shown in the Listing 1 Program.
List of programs 1.
Program for calculating the value of FVC and FEV1

```
void sensing1(){
   dataadc = analogRead(A0);
   tegangan = ((dataadc*5)/1023.00);
   kpa = ((tegangan-0.0875)/0.045);
   v = ((2*kpa*1000/1.98)/5731.00);
   akar = sqrt(v);
   q = (5.30*akar);
   fvc = q-3.28;
   if (fvc<0.17) fvc= 0;

lcd.setCursor(0,1);
lcd.print("FVC= ");
lcd.print(fvc);
lcd.setCursor(9,1);
lcd.print(" Liter");
delay(1000);
simpan[zz] = fvc;
```

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```
zz++;
if(zz > 5){
hasilku = simpan[1] + simpan[2] + simpan[3] + simpan[4]
+ simpan[5];
zz = 0;
return;
}
sensing1();
}

void sensing2()
{
   dataadc = analogRead(A0);
   tegangan = ((dataadc*5.0)/1023.00);
   kpa = ((tegangan-0.0875)/0.045);
   v = ((2*kpa*1000/1.98)/5731.00);
   akar = sqrt(v);
   q = (5.30*akar);
   fev1 = q-3.28;
   if (fev1<0.17) fev1= 0;
lcd.setCursor(0,1);
lcd.print("FEV1= ");
lcd.print(fev1);
lcd.setCursor(10,1);
lcd.print(" Liter");
delay(1000);
hasilku2 = fev1;
return;
}
```

3) Storage of FVC measurements and FEV1 to SD Card Memory

In order for the spirometer to store the results of the diagnosis, the measurement results will be stored on the SD Card to facilitate monitoring of subsequent checks. The Listing Program is displayed as Program Listing 2.

Register Program 2. Program for storing results of FVC and FEV1 measurements

```
void savesd(){
lcd.clear();
lcd.setCursor(0,0);
lcd.print ("Saving...");
delay(3000);


  // Open serial communications and wait for port to open:
  Serial.begin(9600);
  while (!Serial) {
   ; // wait for serial port to connect. Needed for Leonardo
only
  }
  Serial.print ("Initializing SD card...");
  // On the Ethernet Shield, CS is pin 4. It's set as an output
by default.
  // Note that even if it's not used as the CS pin, the
hardware SS pin
  // (10 on most Arduino boards, 53 on the Mega) must be
left as an output
  // or the SD library functions will not work.
  pin Mode(10, OUTPUT);
  if (!SD.begin(4)) {
   Serial.print ("initialization failed!");
   return;
  }
  Serial.print ("initialization done.");
  // open the file. note that only one file can be open at a
time,
  // so you have to close this one before opening another.
  myFile = SD.open("test.txt", FILE_WRITE);
  // if the file opened okay, write to it:
  if (myFile) {
myFile.print("Jenis Kelamin= ");
    if(klm == 1){
    myFile.println("L");
    }
if(klm == 2){
    myFile.println("P");
    }
   myFile.print("Umur= ");
   myFile.println(umur);
   myFile.println("th");
   myFile.print("Tinggi= ");
   myFile.println(tinggi);
   myFile.println("cm");
   myFile.print("FVC= ");
   myFile.println(fvc);
   myFile.print("FEV1= ");
   myFile.println(fev1);
   myFile.print("Rasio= ");
   myFile.println(rasio1);
   myFile.print("Kondisi= ");
   if(ket == 1){
   myFile.println("NORMAL");
   }
   if(ket == 2){
   myFile.println("RESTRIKTIF");
   }
   if(ket == 3){
   myFile.println("OBSTRUKTIF");
   }
   // close the file:
   myFile.close();
   Serial.print ("done.");
  } else {
   // if the file didn't open, print an error:
   Serial.print("error opening test.txt");
  }
  // re-open the file for reading:
  myFile = SD.open("test.txt");
```

```
  if (myFile) {
    Serial.println("test.txt:");
    // read from the file until there's nothing else in it:
    while (myFile.available()) {
      Serial.write(myFile.read());
}

// close the file:
    myFile.close();
  } else {
    // if the file didn't open, print an error:
    Serial.println("error opening test.txt");
  }
lcd.setCursor(0,0);
lcd.print ("DONE...");
delay(1000);
lcd.clear();
}
```

4) Analysis and Measurement Results

The method of this test is by comparing the results of measurements made using two devices, the spirometer, and the module. Then for the data collection was carried out 6 times per respondent's exhales using the module. The process is carried out alternately between the spirometer and the module

TABLE I. TABLE OF FVC AND FEV1 VOLUME MEASUREMENT

ID	Gender	Age	Height	Average (Spirometer)		
				FVC	FEV1	FEV1/FVC
1	P	40	155	2,34	2,33	99,72
2	L	21	160	3,26	3,24	99,49
3	L	21	170	3,32	3,32	99,85
4	P	21	158	2,45	2,45	99,66
5	P	22	168	2,97	2,95	99,15
6	P	22	157	2,60	2,59	99,68
Average				2,82	2,81	99,59
ID	Gender	Age	Height	Average (Modul)		
				FVC	FEV1	FEV1/FVC
1	P	40	155	2,35	2,40	101,73
2	L	21	160	3,32	3,48	105,17
3	L	21	170	3,35	3,42	102,22
4	P	21	158	2,48	2,52	101,75
5	P	22	168	3,00	3,11	102,30
6	P	22	157	2,62	2,59	99,30
Average				2,85	2,92	102,08
%Error				0,98	3,83	2,50

Based on the measurement of FVC and FEV1 values using MPX5100DP compared to the standard device in table 1 shows that the maximum error value of FVC is 0.97%, FEV1 is 3.83% and FEV1 / FVC ratio is 2.50%.

The differences in obtained volume values can be caused by several factors, including the breath of each person cannot be controlled exactly, between the first and second breathing in the same person must have the slightest difference. That was what caused the difference in results between the spirometer tool and the module because the data collected in this study was carried out in different respiration.

IV. DISCUSSION

Overall, this research can conclude that: A Portable Spirometer for Measuring the Health of Lung Functions (FVC and FEV1) has been designed. After the process of literature making and studying for planning, experiments, device testing, and data collection, the authors can conclude as follows: Using a Non-Inverting Amplifier circuit, Arduino-Uno can convert analog data to digital, when the measurement is done on the test point.

Microcontroller circuit is used to process the data generated by non-inverting circuits. The voltage data is processed to the volume by the venturi meter principle. Then the results will be displayed on the LCD, which also show the description of the patient's condition, and will be equipped with a storage system in the SD Card.

Based on the analysis results of statistical data on respondents, the percentage error values have been calculated. If these are averaged then these have an error value of 0.98% in FVC measurements, 3.83% in FEV1 measurements, and 2.50% in FEV1 / FVC ratios. This value is still below the 5% error tolerance limit.

V. CONCLUSION

This research can be developed on equipped with a delete button. Using a sensor other than MPX5100DP in order that there will be a better innovation and measurement. For example, use the flow transducer sensor. Fix or repair the mouthpiece design.

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