Design of Spirometer using Arduino Nano

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Abstract - Spirometers are used to diagnose numerous respiratory conditions including habitual respiratory conditions that affect peoples in worldwide. Most of these people don't have access to a spirometer because current models are more precious and the trained technician must bear to done the process. The purpose of this design is to develop a low- cost spirometer which would be suitable to use without the help of a trained technician. The design includes the physical design of the spirometer, software development to display and assay results. It also uses the Arduino nano as the micro-controller and pressure detector to measure the volume.

Key words: *Low-cost Spirometer, Pressure detector, Arduino Nano*

1. INTRODUCTION

Lung gas exchanges take place through perfusion and ventilation. Perfusion is the passage of blood through the pulmonary capillaries, whereas ventilation is the movement of air in and out of the lungs. Physiological respiration in mammals involves breathing cycles that include both inhaled and expelled breaths. Breathing in is typically an active motion that moves air into the lungs where gas exchange occurs between the blood in the pulmonary capillaries and the air in the alveoli. The pressure variation brought on by the diaphragm's contraction is equivalent to the variations brought on by the elastic, resistive, and inertial parts of the respiratory system. When generating functional overpressure (speaking, singing, humming, laughing, blowing, sneezing, coughing, powerlifting), when exhaling underwater (swimming, diving), at high levels of physiological exertion (running, climbing, throwing), where more rapid gas exchange is required, or in some forms of breath-controlled meditation, exhalation is typically a passive process. Many mammals are unable to maintain sustained breath control, which is necessary for speaking and singing in humans. Each inhalation of atmospheric air (about 350 ml) during breathing does not fill the alveoli with air, however, the functional residual capacity, a significant volume of gas (approximately 2.5 litres in adults), which remains in the lungs after each exhalation and whose gaseous composition differs noticeably from that of the ambient air, is carefully diluted and properly mixed with the inhaled air. The mechanisms that keep the functional residual capacity's composition constant and bring it into equilibrium with the gases dissolved in the body's pulmonary capillary blood are part of physiological respiration. Therefore, in proper usage, the terms breathing and ventilation are hyponyms rather than synonyms of respiration. However, even among health care professionals, this prescription is not consistently followed because the term respiratory rate (RR) has become ingrained in the industry, even though it should be consistently replaced with ventilation rate. As a result of the oxidation-reduction reaction that occurs during respiration, carbon dioxide and water are also created. Cellular respiration is the term for the process through which cells produce energy.

The lungs carry out the process of respiration. Our mouth or nose allow air to initially enter our bodies, moistening and warming it since our lungs can get irritated by cold, dry air. After that, the air passes our voice box and descends into our windpipe. The bronchial tubes are supported by cartilage, which is composed of stiff tissue rings. The bronchial tubes within our lungs divide into countless smaller tubes called bronchioles. Alveoli are collections of microscopic air sacs that form the ends of the bronchioles. We have 150 million alveoli in our lungs. Our alveoli often exhibit elastic properties, allowing for simple changes in size and shape. Because of a chemical called surfactant that coats the interior of alveoli, they can readily expand and contract. By facilitating easier lung expansion upon inhalation, surfactant lessens the effort required to breathe. Additionally, it stops the lungs from compressing when exhaling. These alveoli are made up of a network of microscopic capillaries, which are blood vessels. A network of arteries and veins that transport blood through our body is connected to the capillaries. The blood is delivered to the capillaries that encircle the alveoli by the pulmonary artery and its branches. Low in oxygen and high in carbon dioxide, this blood. Within the alveoli, carbon dioxide is transferred from the blood to the air. Oxygen travels from the air into the capillaries and into the blood at the same moment. The pleura, a membrane with two layers, encircles the lungs. The pleura, a membrane with two layers, encircles the lungs. The pleural cavity refers to the area between these two layers. Pleural fluid, a slick liquid, acts as a lubricant to lessen friction while breathing.

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. 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. 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. Graphical representation of the flow rates and volume is the most important requirement of a spirometer. Thus, a user interface must be designed to express the measured flow rates and volumes in a graphical form. This makes it easy for the practitioner/doctor to interpret the result of the test performed

In this study utilizing the air pressure sensor with an Arduino Nano to collect the lung capacity through LCD display. The main aim of the project is to build the simple, low-cost spirometer that allows for a rough calculation of the volume of air expired from the lungs over a period of time.

2. LITERATURE SURVEY

2.1 Research and development of an IoT based remote Asthma patient monitoring system

Safayat Reza Anan et al.,2021 presents the research on IoT based remote patient monitoring system for Asthma. The study is to design a monitoring system that allows doctors to monitor patients from a remote area. This allows patient to measure oxygen saturation, heart rate, body temperature, humidity, volatile gases, room temperature, and ECG using various sensors which will be displayed in the application. Then data will sent to the doctor to monitor patients condition and appropriate action will be taken.

2.2 Spirometry – based airways disease simulation and recognition using machine learning approaches

Riccardo Di Dio et al.,2021 propose the study to provide means to physicians for automated and fast recognition of airway diseases. This work represents the proof of concept that Machine learning can accurately differentiate disease based on manufactured spirometry data.

2.3 Development of GUI for spirometer and calculation of different spirometric parameters

Isha G Sodhi et al., 2015 points needed to create a Graphical User Interface (GUI) that shows spirometric graphs and computes crucial spirometric parameters that depend on the type of pneumotachometer being used. The created spirometer and a reference spirometer are contrasted in the paper as well.

2.4 Smart spirometer using embedded web server

B. Swathi et al.,2021 established a easy method of testing Asthma and COPD. The proposed prototype is small in size and their motive is to measure the pressure rate, pulse rate and flow rate to identify the Asthma and COPD.

2.5 Development of an electrical impedance based spirometer

Md. Anas Ali et al.,2016 This paper describes the development of an electrical impedance based spirometer placing electrodes on four limbs so that the whole lung volume may contribute to the measurement.

2.6 Design, Development and clinical testing of spirometer

Sushant Kule et al.,2016 refers to a design of computer-based miniaturized spirometer system. This model consists of MSP430 micro controller and pressure sensor. The aim of this design is to bring the low cost spirometer which would help all the people to identify the disorders and take treatment regarding the problems.

2.7 Optical fiber fabry - perot inter-ferometer based spirometer

Ana Catarina Nepomuceno et al., 2021 present an optic fiber grounded device to estimate the pulmonary capacity of individualities through spirometry. The proposed system consists of an optic fiber containing an natural Fabry – Perot interferometer (FPI) micro-cavity attached to a 3D published structure that converts the air inflow into strain variations to the optic fiber, modulating the FPI spectral response.

2.8 IoT based electronic incentive spirometer

Keerthana A et al.,2021 developed a spirometer to detect the chest diseases. The main objective of this project is to develop a flow based incentive spirometer which aid the patient in rehabilitation post lung surgery.

2.9 Portable spirometer using gas sensor

Lia Andriani et al., 2019 proposed a study to develop an affordable spirometer. The main board consists of anon-inverting amplifier, Arduino microcontroller, LCD, and SD card memory. A gas detector is present, the detector's affair is voltage which is converted to a volume of unit using the venturi cadence system.

2.10 Design, analysis and implementation of spirometer

Asmita Parve Mokal et al.,2019 works on the project to develop and validate a mobile spirometer technology based on sensing assembly. The dynamic lung functions test the forced vital capacity, flow volume curves, time-volume curves, maximum voluntary ventilation and airway resistance.

3. HARDWARE DESCRIPTION

The factors used in this design are

- Arduino nano
- MPX5010DP Pressure detector
- Character TV 16 * 2 I2C
- Jumper cables
- Breadboard
- Buzzer
- LED

3.1 Arduino Nano

The ATmega328p-based Arduino Nano is a compact, feature-rich, adaptable, and breadboard-friendly microcontroller board created by Arduino.cc. It has 14 digital legs, 8 analogue legs, 2 reset pins, and 6 power legs. The Arduino IDE, which may be obtained from the Arduino Official Point, is used to programme it. Since Arduino Nano is really a scaled-down version of Arduino UNO, its functionalities are very similar.

Each leg's usefulness is discussed below, along with the pin layout for the Arduino Nano.

- Power Leg (3.3 V, 5 V, GND, Vin) Power legs are what these are
  a) Vin, the board's input voltage, is used when an external power source between 7V and 12V is employed.
  b) The nano board's controlled power force voltage of 5V is employed to supply both the board's force and its factors.
  c) The voltage controller on the board's minimum voltage generator produces 3V.
  d) The board's ground leg is designated as GND.
- Resetting the microcontroller Analogue Pins (A0-A7) requires this leg. These legs are used to determine the board's analogue voltage between 0 and 5 volts.
- Digital Pins from D0 to D13 for I/ O Legs These legs serve as an alternative to other legs 0V & 5V
- Legs for Periodicals (Tx, Rx) To transmit & admit TTL periodic data
- These legs 2 and 3 External Interrupts To start an intrusion, these legs are used.
- PWM (3, 5, 6, 9, 11) With the help of these legs, 8-bit PWM affairs are provided.
- SPI (10, 11, 12, & 13) The SPI communication is supported by these legs.
- Internal LED (13) The LED is ignited by this leg.
- IIC (A4, A5) The TWI communication is supported by these legs.

- AREF This leg is employed to provide the input voltage with a reference voltage.

3.2 Pressure sensor – MPX5010DP

A binary harborage, integrated silicon pressure detector in a six-legged draught package is the MPX5010DP. Modern monolithic silicon pressure detector, this piezoresistive transducer is utilised to detect a wide range of operation. It is perfectly suited for grounded systems with microprocessors or micro regulators. This transducer uses bipolar processing, thin-film metallization, and advanced micromachining techniques to produce an accurate, high position analogue affair signal that is proportional to applied pressure. Artificial grade tubing can now be accommodated in the axial harborage.

The pinout configuration is bandied below

- Leg 1 – Output
- Leg 2 – GND
- Leg 3 - VCC

3.3 LCD display

Liquid crystal display is referred to as LCD. These displays are mostly preferred for seven segments and multi-segment light-emitting diodes. The main advantages of adopting this module are its low cost, ease of programming, animations, and unlimited ability to display bespoke characters, unique animations, etc.

The 16×2 LCD pinout is shown below.

- Leg 1 (Ground/supply Pin): This is the display's GND pin, which is used to connect the microcontroller's GND terminal or a power supply.
- Leg 2 (VCC/Source Pin): This is the display's voltage supply pin, which is utilised to link the power source's supply pin.
- Leg 3 (V0/VEE/Control Pin): This pin controls the display's contrast and is used to connect a movable POT that can provide 0 to 5V.
- Leg 4 (Register Select/Control Pin): This pin switches between the command and data registers. It is used to connect a microcontroller unit pin and receives either 0 or 1 (where 0 corresponds to the data mode and 1 to the command mode).
- Leg 5 (Read/writing/Control Pin): Connected to a microcontroller unit pin to receive either 0 or 1 (where 0 indicates a writing operation and 1 indicates a read operation), this pin toggles the display between reads and writes.
- Leg 6 (Enable/Control Pin) is connected to the microcontroller unit and is always held high. It is used to execute the Read/Write procedure.
- Legs 7 through 14 (Data Pins): Data is sent to the display using these pins. Two-wire configurations, such as the 4-wire and 8-wire modes, are used to connect these pins. In 4-wire mode, the microcontroller unit, such as 0 to 3, only has four pins linked, whereas in 8-wire mode, the microcontroller unit, such as 0 to 7, has eight pins connected.
- Leg 15 (the LED's positive pin) is linked to +5V.
- Leg 16 (the LED's negative pin) is wired to ground (GND).

3.4 Jumper wires

A jumper wire is an electric cable used to link distant printed circuit board electric circuits. It is possible to short-circuit and jump to the electrical circuit by connecting a jumper wire to the circuit.

Here use jumper wires with.

- **MALE-MALE** configuration
- **MALE-FEMALE** configuration
- **FEMALE- FEMALE** configuration

3.5 Bread board

A breadboard, often known as a protoboard, is a construction platform for electronics experimentation. The solderless breadboard is reusable because soldering is not necessary. This makes it simple to utilise for developing temporary prototypes and conducting circuit design experiments. Solderless breadboards are therefore common among students and in technological education. Earlier breadboard models lacked this characteristic. It is difficult to reuse a prototyping circuit board like a stripboard (veroboard), which is used to create one-off or semi-permanent soldered prototypes. Breadboards can be used to prototype a wide range of electronic systems, from tiny analogue and digital circuitry to full-fledged central processing units (CPUs).

3.6 Buzzer

A beeper or buzzer, for example, may be electromechanical, piezoelectric, or mechanical in design. The signal is converted from audio to sound as its primary function. It is often powered by DC voltage and used in timers, alarm clocks, printers, computers, and other electronic devices. It can produce a variety of sounds, including alarm, music, bell, and siren, according on the varied designs. The positive and negative pins are part of the pin arrangement. The '+' symbol or a longer terminal is used to indicate this's positive terminal. While the positive terminal is shown by the '+'symbol or long terminal and is connected to the GND terminal, the negative terminal is represented by the '-'symbol or short terminal.

3.7 LED

When current passes through a light-emitting diode (LED), a semiconductor device, light is released. Recombining electrons and electron holes in the semiconductor results in the release of energy in the form of photons. The energy needed for electrons to bridge the semiconductor's band gap determines the colour of the light, which corresponds to the energy of the photons. Utilising numerous semiconductors or coating the semiconductor device with light-emitting phospour produces white light.

4. SOFTWARE DESCRIPTION

4.1. Arduino development Environment

- The Arduino IDE is an open-source programme created by Arduino.cc that is primarily used for authoring, compiling, and uploading code to virtually all Arduino Modules.
- Because it is an official Arduino programme, code compilation is so simple that even the average individual with no prior technical expertise may get started learning. It runs on the Java Platform and is compatible with all operating systems, including MAC, Windows, and Linux. The Java Platform has built-in functions and commands that are essential for debugging, modifying, and compiling the code.
- A variety of Arduino modules are available, such as the Arduino Uno, Arduino Mega, Arduino Leonardo, Arduino Micro, and many others.
- Each of them has a microcontroller on the board that is actually programmed and takes the data in the programme.
- After being developed on the IDE platform, the main code, often referred to as a sketch, will eventually produce a Hex File that is transmitted and uploaded into the controller on the board.
- The IDE environment primarily consists of two fundamental components: the Editor and the Compiler. The Editor is used to write the necessary code, and the Compiler is used to compile and upload the code into the provided Arduino Module.
- Both C and C++ are supported in this environment.
- There are three key sections that make up the IDE environment.
  - I. Menu Bar
  - II. Text Editor,
  - III. Output Pane
- Sketches are computer programmes created using the Arduino Software (IDE). The text editor is used to create these sketches, which are then saved with the file extension.
- The editor offers functions for text replacement and text searching. When saving and exporting, the message section provides feedback and shows errors.
- The console shows text generated by the Arduino Software (IDE), together with additional information and detailed error messages. The configured board and serial port are visible in the window's bottom right corner. You may create, open, and save sketches, validate and submit programmes, view the serial monitor, and more using the toolbar buttons.

1. setup () is a function that is called just once at the beginning of a programme to initialise settings.

2. till the board turns on, loop () is a function that is called repeatedly.

The bar appearing on the top is called Menu Bar that comes with five different options as follow

- File - You can create a new window or reopen an existing one to write the code. The number of additional categories into which the file option is divided are displayed in the following table.
- The Output Pane will display the code compilation as you click the upload button as soon as you visit the preference area and check the compilation section.
- Edit - Used to copy and paste the code with additional font modifications.
- Sketch is used for compiling and scripting
- Tools are primarily used for testing projects. A bootloader is burned to the new

microcontroller using the Programmer part of this panel.

- Assistance - If you are unsure about the software, full assistance is accessible, from installation to troubleshooting.

Libraries

- Communication (1235)
- Data Processing (313)
- Data Storage (154)
- Device Control (994)
- Display (483)
- Other (467)
- Sensors (1152)
- Signal Input/Output (429)

4.2. Embedded C Language

- The C Standards Committee created Embedded C as a set of language extensions for the C programming language to solve issues of commonality between C extensions for various embedded devices.
- Most of the syntax and semantics found in standard C are used by embedded C, including the main () function, variable definitions, datatype declarations, conditional statements (if, switch case), loops (while, for), functions, arrays and strings, structures and unions, bit operations, macros, etc.
- It is employed in fields like automotive, industrial automation, consumer, aerospace, and medical applications for programming microcontrollers and processors. Because it is a low-level language with direct access to the hardware, it is appropriate for creating applications that must communicate with the hardware directly.
- It has a smaller memory footprint than other languages, which makes it the best choice for usage in memory-constrained applications. Software that is dependable and efficient can be developed using embedded C.

5. METHODOLOGY

- Design: The first step in developing is to design a Spirometer model. This includes defining the overall system architecture, hardware components and algorithms that will be used to process the dada. This design should also include safety and reliability considerations.

- Sensor selection: The next step is to select the sensors that will be used for the construction of spirometer. This includes considering factors such as accuracy, precision, sensitivity, cost and compatibility with the system design.

- Signal processing: Once the sensors have been selected, the signals from the sensors must be processed and analysed to obtain meaningful information about the volume of air respired. This process typically involves signal conditioning, filtering and feature extraction algorithms.

- Here in this chapter the system implementation requirements of the project. The sensors are used in the project for analysing the volume of air respired.

Pressure sensor: In this project pressure sensor is used to collet the data of air we expired. When we blow the air into the pipe, the pressure sensor will collect the data and send it to the micro-controlled (i.e., Arduino nano).

Then the result will be displayed on the LCD screen which would help us to know the volume of air we expired. Additionally, we can add LED and buzzer to give feedback when the test is over.

Arduino nano: Arduino nano is a micro-controller which is used in development of small-scale projects. In spirometer the sensors, buzzer and LEDs are connected to the board send signals to the micro-controller which processes them and provide with desired output.

6. DESIGN AND IMPLEMENTATION

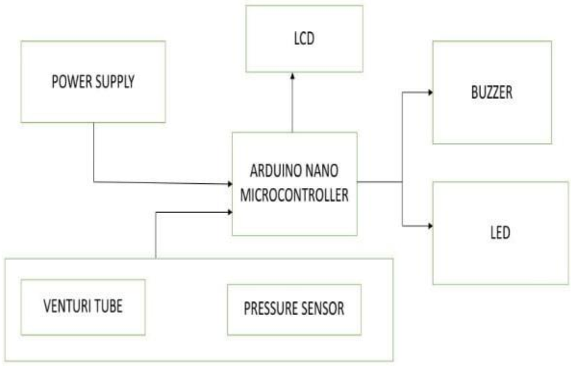

Fig 1 BLOCK DIAGRAM

6.1 Interfacing pressure sensor, LCD display, LEDs, buzzer with Arduino nano

- Connect the Arduino nano to the power supply.
- The pressure sensor is connected to the A0 pin of the Arduino nano.
- The 12C LCD data lines are connected to the pins A4 and A5.
- Then connect the LEDs and buzzer to the Arduino nano.
- Program the Arduino board to receive the input from sensors and display
- Test the connections by sending a signal from the sensor
- Program the Arduino board to display the volume of air in the LCD display
- Test the connections and troubleshoot it any issue that may arise during the process
- Once the components are interfaced properly, test the complete system by measuring the volume of air.

7. RESULT

To use the spirometer, upload the code and blow the air into the tube for five seconds. You can then check the result of spirometer on the LCD screen. Once test is complete then you can press the "reset" button to reset the device for a new test.

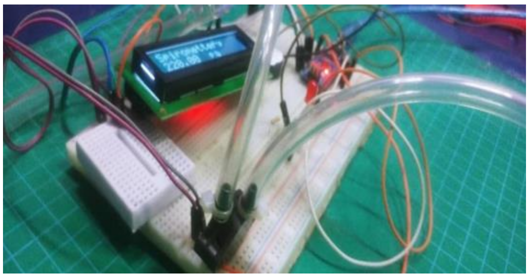

Fig 2 OUTPUT

8. CONCLUSION

Biomedical Engineering is a field of study of bioengineering and technological generalities, which aims to develop outfit and bias for the provision of health care, where the physical, chemical, computer, mathematics and engineering principles are integrated into the study of biology, drug, geste, health, and transplantation of organs, which aims to help, diagnose and treat conditions, in order to rehabilitate the case and ameliorate the health, and the specialty of medical engineering is at the van of the medical revolution, and is achieved through multi-disciplinary conditioning incorporating the other lores with engineering principles. Biomedical masterminds have developed numerous ways that help to grease all aspects of life, and contribute to the saving and preservation of life.

Spirometry testing plays an important part in the opinion and operation of COPD, asthma, restrictive lung complaint, and neuromuscular complaint in the primary care setting. vindicating the delicacy of the spirometer, the use of accurate case demographics and applicable reference equations, and icing testing labor force faculty are crucial factors of spirometry test interpretation. Spirometry interpretation should include an assessment of test quality and be grounded on sound statistical headliners.

The design of spirometer using Arduino nano is used to measure the volume of air we breathed i.e., the capacity of lungs. This system is used to diagnose the lung conditions. In numerous spirometer we've to blow the air for many twinkles and this would be delicate for some people to break the problem we've designed the system which would give the result in many seconds. also, this system is simple, cost effective and useful to people those who are suffered from the lung conditions to diagnose the lung capacity.

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