

ROBUST CONTROL OF AN ARTIFICIAL VENTILATOR

A Project Report Phase - II

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering Degree in Electronics and Communication Engineering

By

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**DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING
SCHOOL OF ELECTRICAL AND ELECTRONICS**

SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

Accredited with Grade “A” by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **J.SHAHIN ROJAR (39130411)** who carried out the project entitled “ **ROBUST CONTROL OF AN ARTIFICIAL VENTILATOR**” under my supervision from January 2023 to April 2023

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A handwritten signature in black ink, appearing to read 'Jack' followed by a stylized circular flourish.

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ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA INSTITUTE OF SCIENCE AND TECHNOLOGY** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

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I consider my self-most fortunate and immensely privileged to have worked under the guidance of **Dr.R.NARMADHA.ME.,Ph.D.**, Department of Electronics and Communication Engineering to complete this project successfully.

I express our heartfelt thanks to our family members and all our friends who helped me to complete our project successfully & finally, I thank the exciting Super Natural Power, the Almighty GOD.

ABSTRACT

Human lungs use the reverse pressure generated by contraction motion of the diaphragm to suck in air for breathing. A contradictory motion is used by a ventilator to inflate the lungs by pumping type motion. A ventilator mechanism must be able to deliver in the range of 10 – 30 breaths per minute, with the ability to adjust rising increments in sets of 2. Along with this the ventilator must have the ability to adjust the air volume pushed into lungs in each breath. The last but not the least is the setting to adjust the time duration for inhalation to exhalation ratio. Apart from this the ventilator must be able to monitor the patient's blood oxygen level and exhaled lung pressure to avoid over/under air pressure simultaneously. In our proposed system, the use of blood oxygen sensor along with sensitive heart Beat sensor to monitor the necessary vitals of the patient and display on a webpage using IoT. To adjust the time duration for inhalation the option command given in the IoT application to set. The entire system is driven by PIC controller to achieve desired results and to assist patients in COVID pandemic and other emergency situations.

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LIST OF ABBREVIATION

ABBREVIATION	EXPANSION
RR	RESPIRATORY RATE
AC	ALTERNATING CURRENT
DC	DIRECT CURRENT
BVM	BAG VALVE MASK
CPU	CENTRAL PROCESSING UNIT
ALU	ARITHMETIC LOGIC UNIT
MU	MEMORY UNIT
CU	CONYROL UNIT

CHAPTER 1

1. INTRODUCTION

The coronavirus pandemic is a major health emergency, as of 15 July, the World Health Organization (WHO) has reported over 1.3 Million of confirmed coronavirus cases all over the world. According to data provided by WHO, 80% of confirmed coronavirus cases will be able to recover without the need for hospitalization. However, 1 in 6 patients could have significant aggravated symptoms, causing damage to the lungs and therefore decreasing the levels of oxygen in the body. In this sense for patients with severe effects of the infection, an artificial ventilator may offer the best chance of survival.

A DIY ventilator may not be effective as that of a medical grade ventilator yet it can go about as a decent substitute in the event that it has authority over the accompanying key boundaries. It is also combined with robust blood oxygen measuring sensor. Pulse oximetry might be utilized in both inpatient and outpatient settings. In some cases, your doctor may recommend that you have a pulse oximeter for home use. During a pulse oximetry perusing, a little clamp like device is set on a finger, earlobe, or toe. Little light emissions go through the blood in the finger, estimating the measure of oxygen. It does this by estimating changes of light absorption in oxygenated or deoxygenated blood. This is a painless process.

Yet this reliable and affordable DIY ventilator during Covid pandemic times. After designing this model these models are distributed and, on the web, so that others can also use it and design their own ventilator, even at the small scale. Artificial ventilators play a critical role in managing the respiratory distress of patients with severe respiratory illnesses, such as COVID-19. To ensure that patients receive optimal care, it is essential to maintain accurate control of the ventilation parameters, such as the respiratory rate, tidal volume, and positive end-expiratory pressure (PEEP). However, variations in patient anatomy and lung compliance, as well as external disturbances, can significantly affect the performance of the ventilator, leading to potential harm to the patient.

Robust control techniques offer a promising solution to these challenges, providing a systematic approach to designing controllers that can handle variations in the patient's condition and external disturbances. In this report, we discuss the

design of a robust controller for an artificial ventilator that can maintain stable and safe ventilation under a range of conditions. We review the relevant literature on robust control techniques and explore their applicability to the design of artificial ventilator control systems. Finally, we present simulation results demonstrating the effectiveness of the proposed robust controller in maintaining stable and safe ventilation.

Robust control is a powerful technique for designing control systems that can maintain stability and performance under a range of operating conditions. In the field of biomedical engineering, robust control has been widely used to design controllers for medical devices, including artificial ventilators. The use of robust control techniques in ventilator design can help to ensure that patients receive optimal ventilation therapy, even in the presence of variations in patient anatomy and lung compliance or external disturbances.

In this report, we present an overview of robust control techniques for the design of an artificial ventilator control system. The report is organized as follows. First, we provide a brief introduction to artificial ventilation and the importance of robust control in this context. Next, we review the relevant literature on robust control techniques, including model-based and data-driven methods. We then discuss the application of these techniques to the design of artificial ventilator control systems, including the selection of appropriate models and control algorithms. Finally, we present simulation results demonstrating the effectiveness of the proposed robust controller in maintaining stable and safe ventilation.

Artificial ventilation is a critical intervention for patients with respiratory failure, such as those with severe COVID-19. The primary goal of artificial ventilation is to provide mechanical support to the respiratory system, allowing the patient to maintain adequate oxygenation and ventilation. The ventilation parameters, including the respiratory rate, tidal volume, and PEEP, must be carefully controlled to avoid potential harm to the patient. Variations in patient anatomy and lung compliance, as well as external disturbances, can significantly affect the performance of the ventilator, making robust control essential in ensuring optimal patient outcomes.

1.1 ROBUST CONTROL TECHNIQUES

Robust control techniques provide a systematic approach to designing

controllers that can handle variations in the patient's condition and external disturbances. These techniques can be divided into two categories: model-based and data-driven methods. Model-based methods rely on mathematical models of the ventilator-patient system to design control algorithms that can handle variations in patient condition and external disturbances. These models typically include representations of the lung mechanics, airway resistance, and compliance, as well as the ventilator's mechanical characteristics. Control algorithms based on model-based techniques include classical control, such as PID and state-space control, and modern control, such as H-infinity and mu-synthesis.

Data-driven methods, on the other hand, rely on data collected from the ventilator-patient system to design control algorithms that can handle variations in patient condition and external disturbances. These methods are particularly useful in situations where a reliable mathematical model of the system is not available or when the model is too complex to be useful in designing a control algorithm. Data-driven methods include machine learning techniques, such as neural networks and fuzzy logic, as well as adaptive control.

The application of robust control techniques to the design of artificial ventilator control systems requires the selection of appropriate models and control algorithms. The selection of appropriate models involves a trade-off between model complexity and accuracy, with more complex models typically providing more accurate representations of the system but at the cost of increased computational complexity. Control algorithms must be designed to handle variations in patient condition and external disturbances while maintaining stable and safe ventilation.

The use of robust control techniques in the design of artificial ventilator control systems can help to ensure that patients receive optimal ventilation therapy, even in the presence of variations in patient anatomy and lung compliance or external disturbances. The selection of appropriate models and control algorithms is critical in the application of robust control techniques to this context. In the following sections, we will review the relevant literature on robust control techniques and discuss their application to the design of artificial ventilator control systems.

1.2 ARTIFICIAL VENTILATORS

Artificial ventilators, also known as mechanical ventilators, are medical devices that provide mechanical support to the respiratory system of patients who are unable to breathe adequately on their own. The use of artificial ventilators is essential in the treatment of respiratory failure caused by various medical conditions, such as pneumonia, chronic obstructive pulmonary disease (COPD), and acute respiratory distress syndrome (ARDS). The COVID-19 pandemic has highlighted the critical role of artificial ventilators in treating patients with severe respiratory symptoms.

In this report, we provide an overview of artificial ventilators and their use in the treatment of respiratory failure. We discuss the different types of artificial ventilators, their components, and the key ventilation parameters that must be controlled to ensure optimal patient outcomes. We also review the relevant literature on the use of artificial ventilators in the context of the COVID-19 pandemic and the challenges associated with their use.

Artificial ventilators can be classified into two main categories: invasive and non-invasive. Invasive ventilation involves the insertion of a tube into the patient's airway through the mouth or nose, while non-invasive ventilation involves the use of a mask that covers the patient's nose and mouth or the use of a nasal cannula. Invasive ventilation is typically used for patients with severe respiratory failure, while non-invasive ventilation is used for patients with mild to moderate respiratory failure.

The components of an artificial ventilator include a breathing circuit, a gas source, a control system, and sensors. The breathing circuit delivers the gas mixture to the patient's airway and collects the exhaled gas. The gas source provides the gas mixture, typically oxygen and air, to the breathing circuit. The control system controls the ventilation parameters, including the respiratory rate, tidal volume, and positive end-expiratory pressure (PEEP), to ensure adequate oxygenation and ventilation. The sensors measure the patient's respiratory parameters and provide feedback to the control system. The key ventilation parameters that must be controlled during artificial ventilation include the respiratory rate, tidal volume, and PEEP. The respiratory rate refers to the number of breaths delivered per minute, while the tidal

volume refers to the volume of air delivered in each breath. The PEEP refers to the positive pressure maintained in the patient's airway at the end of expiration, which helps to prevent the collapse of the alveoli and improve oxygenation. The control of these parameters is critical in ensuring optimal patient outcomes and avoiding potential harm to the patient.

The use of artificial ventilators in the context of the COVID-19 pandemic has posed significant challenges, including the shortage of ventilators and the need to rapidly increase their production. The design and manufacture of artificial ventilators require specialized expertise and equipment, making it challenging to meet the high demand for these devices. The COVID-19 pandemic has also highlighted the importance of ensuring the safety and effectiveness of artificial ventilators, as their use can lead to serious complications, including lung injury and infection.

Artificial ventilators are critical medical devices that provide mechanical support to the respiratory system of patients with respiratory failure. The selection of appropriate ventilation parameters and the control of these parameters are essential in ensuring optimal patient outcomes. The COVID-19 pandemic has highlighted the critical role of artificial ventilators in treating patients with severe respiratory symptoms and the challenges associated with their use. In the following sections, we will discuss the design and control of artificial ventilators in more detail, with a particular focus on the use of robust control techniques to ensure their safe and effective use.

CHAPTER 2

LITERATURE SURVEY

This chapter discusses about extensive literature robust control of an artificial Ventilator.

2.1 LITERATURE SURVEY

Balamurugan C.R., Kasthuri A., Malathi E. Dharanidharan S., Hariharan D., Kishore B.V., Venkadesh T., (Design of Ventilator Using Arduino for Covid Pandemic) (01 April 2021). This ventilator is made with push mechanism in each breath. This ventilator is very cheap and affordable. Motor mechanism is used push the air bag. When oxygen level count is low this mechanism is performed. Small screen is used to display the oxygen level at real time. The entire system is controlled with Arduino. If the oxygen level is low the buzzer is ring. Toggle are switching and variable pot to check the breath length and BPM level of patients.

Leonardo Acho, Alessandro N. Vargas, Gisela Pujol-Vázquez, (Low-Cost, Open Source Mechanical Ventilator with Pulmonary Monitoring for COVID-19 Patients) (12 September 2020). This article shows that construction of low-cost, open-source mechanical ventilator. This article also shows that numerical method for monitoring patients pulmontory condition. With the help of pressure sensor, we can classify the patients are healthy or unhealthy lungs. An Arduino board collects the information from pressure sensor and sends them to raspberry pi. The raspberry pi commands the acutor and breathing bag compress accordingly. According to manufacture the pressure sensor can measure differentially pressure of up to 70 cm H₂O. the gear was attached to the servo meter rod. The rod was made by plexi glass bar. The radius of this gear is 2.5cm.

Aliaksei Petsiuk, Nagendra G. Tanikella, Samantha Dertinger, Adam Pringle, Shane Oberloier, Joshua M. Pearce, (Partially Rep Rapable automated open source bag valve mask-based ventilator). This article shows that development of simple and easy to build portable automated mask value bag. This handle with Arduino controller with real time operating system installed on largely rep rap 3d printable parameter component based structure. For Arduino extensively grows the conceivable outcomes of the controller. A real-time operating system gives

fundamental capacities to software tasks, like planning, dispatching, inter-task communication.

Couchman, B. A. et al. (Nurses role in prevention and management of mechanical ventilation related complications) (2006). In their article titled, nursing care of the mechanically ventilated patient: What does the evidence say? summarized as nursing care and management of mechanically ventilated patient is challenging and requires nursing expertise for knowing the technological issues undying the patient cantered approach. Mechanical ventilation precipitates several actual and potential complications for the critically ill clients. Use of ventilator care is effective in mechanically ventilated patients producing positive outcomes which consists of four interventions, those are; elevation of head of the bed, sedation vacation, peptic ulcer prophylaxis and deep vein thrombosis prophylaxis. The nursing care practice lacks in supportive significant evidence for proving one care approach is better than the other. In the care of mechanically ventilated patient the best nursing care practice is the use of evidence-based practice conjunction with comprehensive and systematic patient.

Vikky Bhakre*, Ajay Pathrabe, Journal of Optoelectronics and Communication Volume 3 Issue 2 ,HBRP Publication Page 1-5 (2021) Journal .DIY Ventilator using Arduino with blood oxygen sensing for covid pandemic. ventilator bag driven by Direct Current motors, 2 side push mechanism to push the air bag. Toggle for switching, variable pot to check the breath length ,BPM levels of the patient. There is a lot of Future work to be upgraded to make it medical grade hardware. The team of engineers and clinicians designed and tested an emergency ventilator that uses a single limb portable ventilator circuit. Ventilator performance was assessed using an IngMar ASL 5000 breathing simulator, and it was compared with a commercially available mechanical ventilator. The emergency ventilator provides volume control mode, intermittent mandatory ventilation and continuous positive airway pressure.

2.2 LITERATURE SUMMARY

Describes the design and implementation of a low-cost ventilator using an Arduino microcontroller for patients with low oxygen levels. The system uses a push mechanism controlled by a motor to inflate the air bag and a small screen to display real-time oxygen levels. Toggle switches and variable pots are used to adjust the

breath length and breathing rate. In contrast, the second article by Acho et al. presents an open-source mechanical ventilator with a pulmonary monitoring system for COVID-19 patients. The system uses a pressure sensor to monitor the patients' lung condition, and an Arduino board collects the data and sends it to a Raspberry Pi for processing.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

Coronavirus, a dangerous disease caused by a virus which got spread two years back, made our lives up and down. Many people died because of this virus due to lack of medicinal facilities. It infects our respiratory system also. It is very difficult to breathe. In case if a patient suffers from respiratory failure mechanical ventilators are needed. Ventilator is a medical device used for the breathing process. Ventilators are needed to treat influenza and coronavirus and people in intensive care units (ICU). Before Covid times only people in intensive care units used ventilators but after a heavy spread of corona demand for ventilators increased.

Ventilator helps in pumping air into the lungs. People with coronavirus need a ventilator because they feel difficulty in breathing or they do not have sufficient oxygen levels. Whereas due to the heavy spread of corona there is a shortage of ventilators. There is a lack of ventilators for many medical units. This is not necessary. Some countries developed ventilators which are dangerous for human lives which are small in volume. Yet this reliable and affordable DIY ventilator during Covid pandemic times. After designing this model these models are distributed and on the web so that others can also use it and design their own ventilator, even at the small scale.

3.2 EXISTING SYSTEM

The most pressing shortages facing hospitals during the COVID-19 emergency is a lack of ventilators. These machines can keep patients breathing when they no longer can on their own and they can cost around \$30,000 each. Design and development of a low-cost portable ventilator could be a possible way, that can help pneumonia cases of COVID-19 patient.

3.3 PROPOSED SYSTEM

Proposed low-cost ventilator delivers breaths by compressing a conventional Bag Valve Mask (BVM) or Ambu bag with a pivoting motor drive mechanism, eliminating the need for a human operator. Proposed low-cost ventilator delivers breaths by compressing a conventional Bag Valve Mask (BVM) or Ambu bag with

apivoting motor drive mechanism, eliminating the need for a human operator. Among other features, the machine should have invasive and non-invasive feature, and supports 500-600 mL tidal volume, with a continuous working capability for several days. Based on calculation, 12 Respiratory rate (RR)/min can provide required amount of tidal volume to the pneumonia patient. Strategy of automatic arm actuated BVM compression is proven to be a viable option to achieve low-cost, low-power and portable ventilator technology that provides essential ventilator features at a fraction of the cost of existing models.

3.3.1 ADVANTAGES

1. The overall system efficiency with regard to:
2. Speed
3. Easy to Use

3.3.2 LIMITATIONS OF VENTILATOR

1. High cost
2. No portable
3. Human's need to regularly monitor the entire system.

3.4 SCOPE AND APPLICATION

3.4.1 FUTURE SCOPE

1. If the blood oxygen level low, then it automatically calls the doctor or ambulance.
2. And the particular location will be shared through GSM using GPS unit.

3.4.2 APPLICATIONS

1. Hospitals & Home ,
2. Medical sector's ,
3. Hospitals ,
4. clinics ,
5. First Aid Centres,
6. Emergency Situation

CHAPTER 4

MATERIALS AND METHODS

3.5 HARDWARE COMPONENTS

3.5.1 BAG VALVE MASK (BVM) OR AMBU BAG:

Used for resuscitation in emergency situations, available at local chemists. • Compressible self-refilling ventilation bag with non-re breathing patient valve with pressure limitation valve to minimize the risk of overinflating. • 100% latex free.



Figure 1: Bag Valve Mask (BVM) or Ambu Bag

3.5.2 PIC MICROCONTROLLER:

PIC microcontrollers can be used in CAN bus-based projects. In general, any type of PIC microcontroller can be used, but some PIC microcontrollers (e.g. PIC18F258) have built-in CAN modules that simplify the design of CAN bus-based systems. Microcontrollers with no built-in CAN modules can also be used in CAN bus applications, but additional hardware and software are required, making the design costly and also more complex. PIC microcontrollers come in a range of sizes and capabilities, from small 8-bit microcontrollers to powerful 32-bit devices with advanced peripherals. They are used in a wide range of applications, including automotive systems, medical devices, consumer electronics, and industrial automation. PIC microcontrollers are programmed using a variety of programming languages and software development tools, making them accessible to both hobbyists and professional engineers.

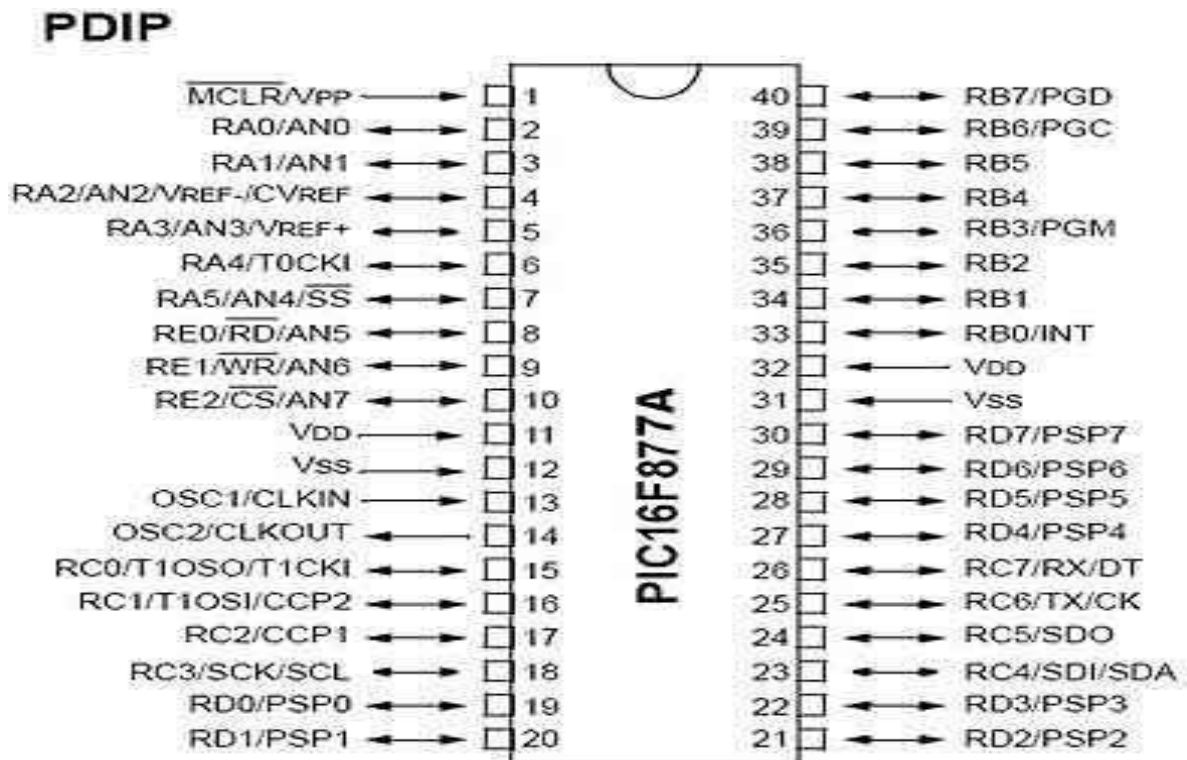


Figure 2: Pic Microcontroller

PIC Microcontroller architecture is based on Harvard architecture and supports RISC architecture (Reduced Instruction Set Computer). PIC microcontroller architecture consists of memory organization (ram, rom, stack), CPU, timers, counter, ADC, DAC, serial communication, CCP module and I/O ports. PIC microcontroller also supports the protocols like CAN, SPI, UART for interfacing with other peripherals. PDIP stands for Plastic Dual In-line Package. It is a type of packaging for integrated circuits (ICs) and other electronic components. The PDIP package has two rows of pins that extend from the bottom of the package, with a plastic body encasing the IC.

The pins are arranged in a grid pattern with a standard spacing, making them easy to insert into a circuit board or socket. The PDIP package is a common type of IC package, used for a wide range of applications including microcontrollers, digital signal processors, and voltage regulators. The compact size and standardized pin layout of the PDIP package make it a popular choice for many electronic designs.

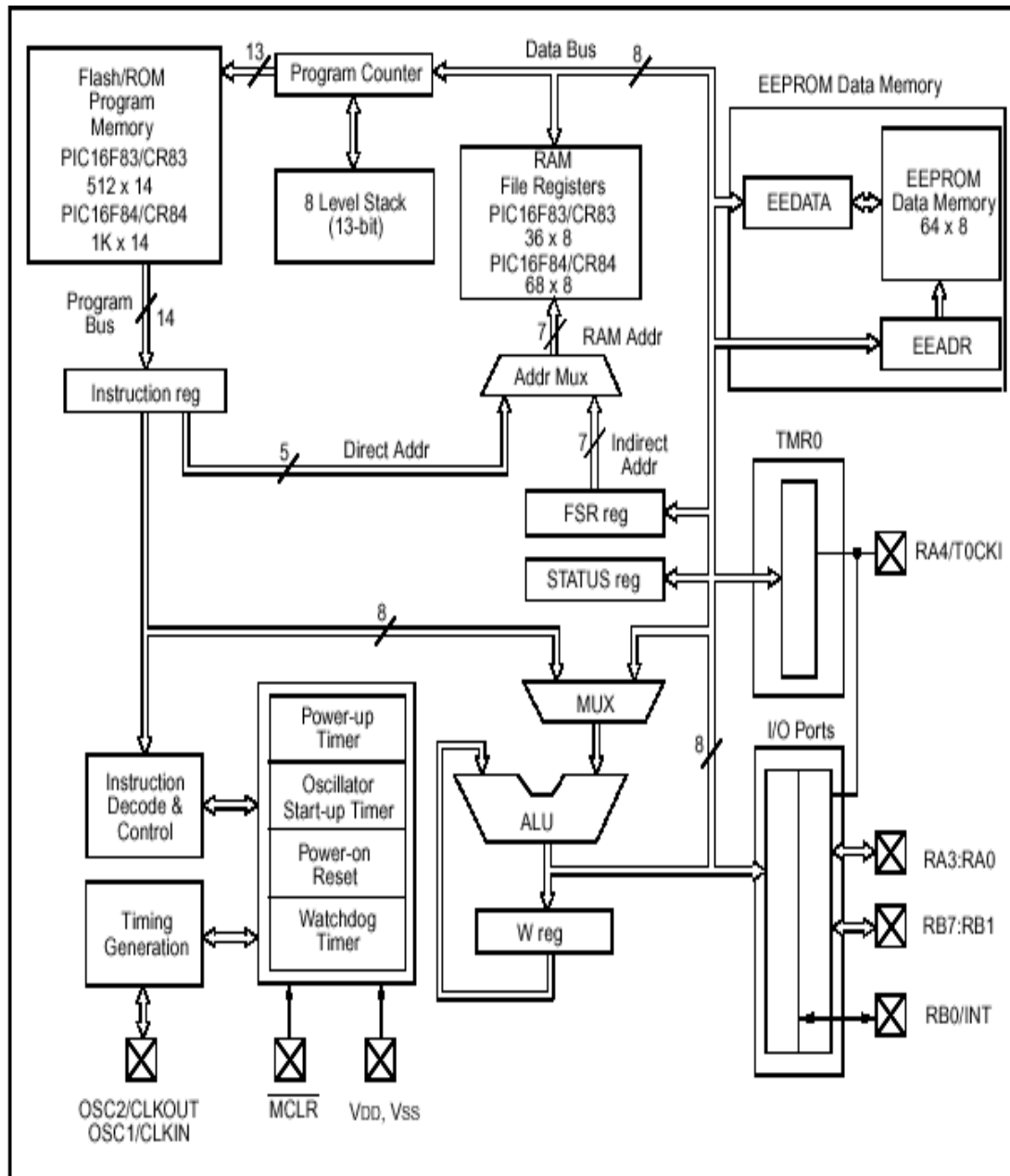


Figure 3: ARCHITECTURE DIAGRAM

3.6 PIC ARCHITECTURE

3.6.1 CPU (Central Processing Unit):

PIC microcontroller's CPU consists of

- Arithmetic logic unit (ALU)
- Memory unit (MU)
- Control unit (CU)

- Accumulator

ALU is used for arithmetic operations and for logical decisions. Memory is used for storing the instructions after processing. Control unit is used to control the internal and external peripherals which are connected to the CPU and accumulator is used for storing the results.

3.6.2 MEMORY ORGANIZATION:

PIC microcontroller memory module consists of mainly 3 types of memories:

- **PROGRAM MEMORY:**

It contains the written program after we burned it in microcontroller. Program Counter executes commands stored in the program memory, one after the other. Pic microcontroller can have 8K words x 14 bits of Flash program memory that can be electrically erased and reprogrammed. Whenever we burn program into the micro, we erase an old program and write a new one.

- **DATA MEMORY:**

It is a RAM type which is used to store the data temporarily in its registers. The RAM memory is classified into banks. Each bank extends up to 7Fh (128 bytes). Number of banks may vary depending on the microcontroller. PIC16F84 has only two banks. Banks contain Special Function Registers (SFR) and General Purpose Registers (GPR). The lower locations of each bank are reserved for the Special Function Registers and upper locations are for General Purpose Registers.

General Purpose Registers (GPR):

These registers don't have any special function. These are used for general purpose for multiplying, addition or subtraction and then storing the results in other registers. CPU can easily access the data in these registers.

Special Function Registers (SFR):

These registers are used for special purposes and they cannot be used as normal registers. Their function is set at the time of manufacturing. They perform the function assigned to them and user cannot change the function of SFR. Three important SFRs for programming are:

STATUS register: It changes the bank

PORT registers: It assigns logic values 0 or 1 to the ports

TRIS registers: It is a data direction register for input and output

DATA EEPROM:

This memory allows storing the variables as a result of burning the written program. It is readable and writable during normal operation (over the full VDD range). This memory is not directly mapped in the register file. It is indirectly addressed through the SFRs. There are six SFRs which are used to read and write to this memory (EECON1, EECON2, EEDATA, EEDATH, EEADR, EEADRH).

SERIAL COMMUNICATION:

The transfer of one bit of data at time consecutively over a communication channel is called Serial Communication. There are three protocols of serial communication:

- **USART:** It stands for Universal synchronous and Asynchronous Receiver and Transmitter which provides a serial communication in two devices. In this protocol data is transmitted and received bit by bit through a single wire according to the clock pulses. To send and receive data serially the PIC microcontroller has two pins TXD and RXD.

SPI PROTOCOLS:

SPI stands for Serial Peripheral Interface. It is used to send data between PIC microcontrollers and other peripherals like sensors, shift registers and SD cards. Three wire SPI communications is supported in PIC microcontroller between two devices on a common clock source. SPI protocol has greater data handling capability than that of the USART. I2C Protocol: I2C stands for Inter Integrated Circuit, and this protocol is used to connect low speed devices like microcontrollers, EEPROMS and A/D converters. PIC microcontroller support two wire Interface or I2C communication between two devices which can work as both Master and Slave device.

3.7 SERIAL COMMUNICATION

3.7.1 INTERRUPTS:

There are 20 internal interrupts and three external interrupt sources in PIC microcontrollers which are related with different peripherals like ADC, USART, Timers, and CCP etc.

3.7.2 I/O PORTS:

Let us take PIC16 series, it consists of five ports, such as Port A, Port B, Port C, Port D and Port E.

- **Port A:** This port is 7-bit wide and can be used for both input and output. The status of TRISA register decided whether it is used as input or output port.
- **Port B:** It is an 8-bit port. This port also can be used as input and output. More over in input mode four of its bits are variable according to the interrupt signals.
- **Port C:** It is also an 8-bit port and can be used as both input and output port which is determined by the status of the TRISC register.
- **Port D:** This 8-bit port, unlike Port A, B and C is not an input/output port, but is used as acts as a slave port for the connection to the micro processor . When in I/O mode Port D all pins should have Schmitt Trigger buffers.
- **Port E:** It is a 3-bit port which is used as the additional feature of the control signals to the A/D converter.

3.7.3 CCP MODULE:

A CCP module works in the following three modes:

- **Capture Mode:** In this mode time is captured when a signal is arrived, or we can say that, when the CCP pin goes high it captures the value of the Timer1.
- **Compare Mode:** It works same as an analog comparator, which means that when timer 1's value reaches some reference value it will give an output signal.
- **PWM Mode:** This mode provides a 10 bit resolution pulse and duty cycle that is programmed.

Timers:

Timers and counters are important as timers can tell the time and count. PIC microcontroller can have up to four timers (depending upon the family) Timer0, Timer1, Timer2 and Timer3. Timer0 and Timer2 are of 8-bits while the Timer1 and Timer3 are of 16-bits, which can also be used as a counter. These timers work according to the selected modes.

3.7.4 D/A CONVERTER:

There are no analog outputs in PIC Microcontroller. To get analog output we have to use external Digital-to-Analog Converter (DAC). It can convert 8 bits of digital number from the eight digital outputs of PIC microcontroller.

A/D CONVERTER

It converts the analog voltage levels to digital voltage values. In PIC Microcontroller, ADC has 8-channels and has resolution of 10-bit, which means that if we have to convert an analog voltage between 0V to 5V the converter will divide it to 2^{10} levels (1024 levels). The special function registers ADCON0 and ADCON1 control the operation of ADC. The converter stores the lower 8 bits in ADRESL register and the upper bits in the ADRESH register. Reference voltage of 5V is required for the operation of the converter. An A/D converter, or analog-to-digital converter, is a device that converts an analog signal into a digital representation.

The analog signal can be a voltage, current, temperature, or any other continuous signal. The A/D converter samples the analog signal at a fixed interval and generates a digital representation of the signal, typically in the form of a binary number. The resolution of the A/D converter determines the number of discrete values that the analog signal can be represented with. Higher resolution A/D converters are able to represent the analog signal with more accuracy and detail. A/D converters are commonly used in a wide range of applications including data acquisition, control systems, and instrumentation. A/D converters are commonly used in data acquisition systems to convert analog signals from sensors or other input devices into digital form for processing and analysis. A/D converters are used in control systems .

3.7.5 MOTOR CONTROLLER L298:

Motor Controller is used to control the direction of DC motor. It consists of an L298 motor driver IC which is capable of rotating the motor in both clockwise and anti-clockwise directions by switching its pins from HIGH to LOW and vice versa. Required +12V, GND and +5V in order to power it up. So, we will design a voltage regulator which will stepdown 12V to 5V. Using L298 microcontroller, 2 DC motors can easily operate. So simply by adding another DC motor with ambu bag setup can operate 2 ventilation system at the same time.

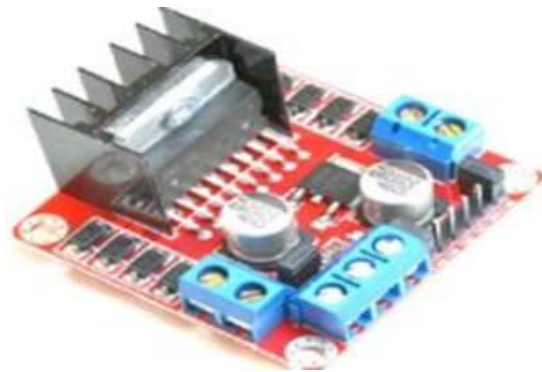


Figure 4: L298 MOTOR DRIVER

3.7.6 DC Gear Motor:

For this prototype used 12V DC gear motor of 7 kg/cm torque capacity. Speed(RPM): 7-600RPM and 0.15A is suitable for proposed design.



Figure 5: DC MOTOR

3.8 ARDUINO UNO

Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input / output pins (of which 6 can be used as PWM outputs), 6 analog inputs, 16 MHz ceramic resonator, USB connection, power jack, ICSP plug, and a reset button. It contains everything needed to support the microcontroller; simply use the USB cable or power it with a AC-to-DC adapter or battery is connected to a computer begins.



Figure 6: Arduino Uno

3.8.1 I2C LCD DISPLAY

At the heart of the adapter is an 8-Bit I/O Expander chip – PCF8574. This chip converts the I2C data from an Arduino into the parallel data required by the LCD display. The board also comes with a small trim pot to make fine adjustments to the contrast of the display. In addition, there is a jumper on the board that supplies power to the backlight. To control the intensity of the backlight, you can remove the jumper and apply an external voltage to the header pin that is marked as 'LED'.



Figure 7: LCD DISPLAY

3.8.2 PRESSURE SENSOR

The MPL3115A2 is a compact, piezoresistive, absolute pressure sensor with an I2C digital interface. MPL3115A2 has a wide operating range of 20 kPa to 110 kPa, a range that covers all surface elevations on earth. The MEMS is temperature compensated utilizing an on-chip temperature sensor. The pressure and temperature data is fed into a high resolution ADC to provide fully compensated and digitized outputs for pressure in Pascals and temperature in °C..MPL3115A2's advanced ASIC has multiple user programmable modes such as power saving, interrupt and autonomous data acquisition modes, including programmed acquisition cycle timing, and poll-only modes. Typical active supply current is 40 μ A per measurement- second for a stable 10 cm output resolution.

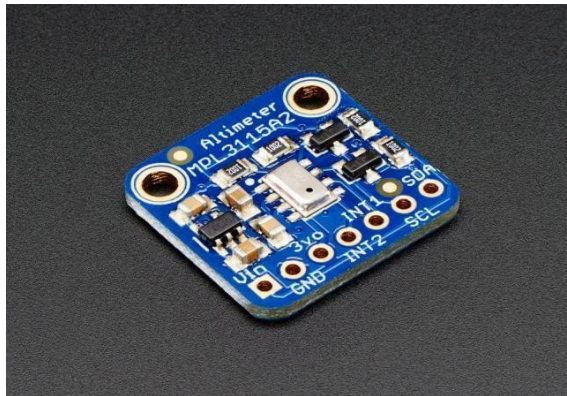


Figure 8: PRESSURE SENSOR

3.8.3 HEART RATE SENSOR

Pulse Sensor is a low cost, very small size a plug-and-play heart rate sensor for Arduino and Arduino compatible boards. It can be used by students, artists, athletes, makers, and game & mobile developers who want to easily incorporate live heart- rate data into their projects. Pulse Sensor Amped adds amplification and noise cancellation circuitry to the hardware. It's noticeably faster and easier to get reliable pulse readings. Pulse Sensor works with either a 3V or 5V Arduino. A Color-Coded Cable, with a standard male header connectors. Plug it straight into an Arduino or a Breadboard. No soldering is required. An Ear Clip, perfectly sized to the sensor. It can be hot-glued or epoxied to the back of the sensor to get reading from an ear lobe.



Figure9: HEART BEAT SENSOR

3.8.4 DHT11 SENSOR

The DHT11 is a basic, ultra low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). Its fairly simple to use, but requires careful timing to grab data.

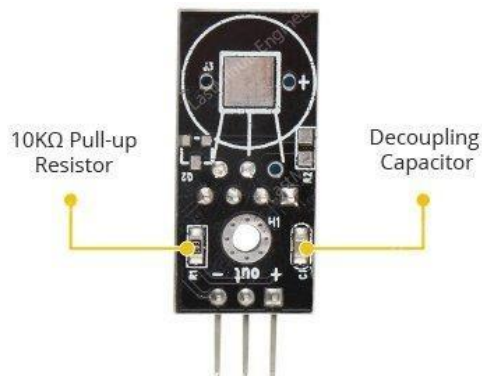


Figure 10: DHT11 SENSOR

3.8.5 TRANSFORMER

Transformer is a general purpose chassis mounting mains transformer. Transformer has 230V primary winding and non-center tapped secondary winding. The transformer has flying colored insulated connecting leads (Approx 100 mm long). The Transformer act as step down transformer reducing AC - 230V to AC - 12V. The Transformer gives outputs of 12V and 0V. The Transformer's construction is written below with details of Solid Core and Winding. The transformer is a static electrical device that transfers energy by inductive coupling between its winding circuits. A varying current in the primary winding creates a varying magnetic flux in the transformer's core and thus a varying magnetic flux through the secondary winding.

This varying magnetic flux induces a varying electromotive force (E.M.F) or voltage in the secondary winding. The transformer has cores made of high permeability silicon steel. The steel has a permeability many times that of free space and the core thus serves to greatly reduce the magnetizing current and confine the flux to a path which closely couples the winding.



Figure 11: TRANSFORMER

A Bridge rectifier is an Alternating Current (AC) to Direct Current (DC) converter that rectifies mains AC input to DC output. Bridge Rectifiers are widely used in power supplies that provide necessary DC voltage for the electronic components or devices. They can be constructed with four or more diodes or any other controlled solid-state switches. We can find this rectifier in a wide variety of electronic AC power devices like home appliances, motor controllers, modulation

process, welding applications, etc.



Figure 12: VOLTAGE REGULATOR

3.8.6 IC 7805 VOLTAGE REGULATOR

It is a three-pin IC; input pin for accepting incoming DC voltage, ground pin for establishing ground for the regulator, and output pin that supplies the positive 5 volts. Input Voltage: Minimum 7V, Maximum 25V Output Current: 1.5A Operating Virtual Junction Temperature: Minimum 0, Maximum 125°C Possible High Temperatures .If differences between the input and output voltages are not well managed, LM7805 can overheat, which may result in malfunctioning. Solutions Include: Limiting input voltage to 2-3 volts above the output regulated voltage.

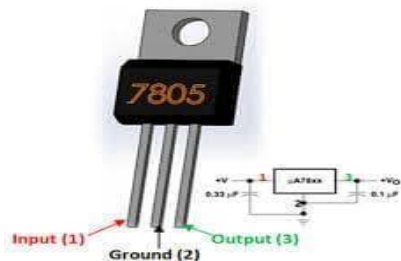


Figure 13: VOLTAGE REGULATOR 7805

3.8.7 IC 7812 VOLTAGE REGULATOR

LM7812 is a TO-220 packaged positive voltage regulator IC of LM78xx series that is manufactured by many different electronic components manufacturers. The IC provides fixed 12V output voltage no matter if the input voltage is fluctuating or changing continuously or it is higher than 12V but the input voltage should not be more than 35V which is the maximum input voltage limit this IC is capable to handle.

Moreover the input voltage should not be less than 14V that is the minimum input voltage requirement of the IC to provide fixed 12V output. During usage when the IC performing voltage regulation or stepping down the input voltage all the voltage difference between the input voltage and the output is converted to heat due to which a suitable heatsink is mandatory for proper working of the IC. The IC can handle maximum load of 1A to 1.5A but the input current should be 2A to get 1A

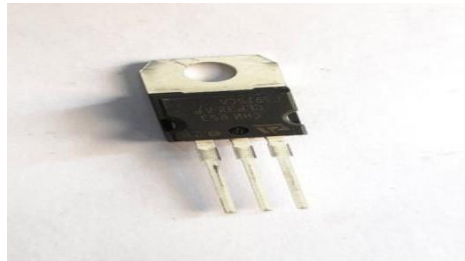


Figure 14: VOLTAGE REGULATOR 7812

3.9 ARDUINO IDE

The Arduino Integrated Development Environment (IDE) is a cross- platform application (for Windows, macOS, Linux) that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. The source code for the IDE is released under the GNU General Public License, version 2. The Arduino IDE supports the languages C and C++ using special rules of code structuring.

The Arduino IDE supplies a software library from the Wiring project, which provides many common input and output procedures. User-written code only requires two basic functions, for starting the sketch and the main program loop, that are compiled and linked with a program stub `main()` into an executable cyclic executive program with the GNU toolchain, also included with the IDE distribution.

3.9.1 IoT PAGE

The Internet of Things, or IoT, refers to the billions of physical devices around the world that are now connected to the internet, all collecting and sharing data. Thanks to the arrival of super-cheap computer chips and the ubiquity of wireless networks, it's possible to turn anything, from something as small as a pill to

something as big as an aero plane, into a part of the IoT.

Connecting up all these different objects and adding sensors to them adds a level of digital intelligence to devices that would be otherwise dumb, enabling them to communicate real-time data without involving a human being. The Internet of Things is making the fabric of the world around us more smarter and more responsive, merging the digital and physical universes.

3.10 BLOCK DIAGRAM

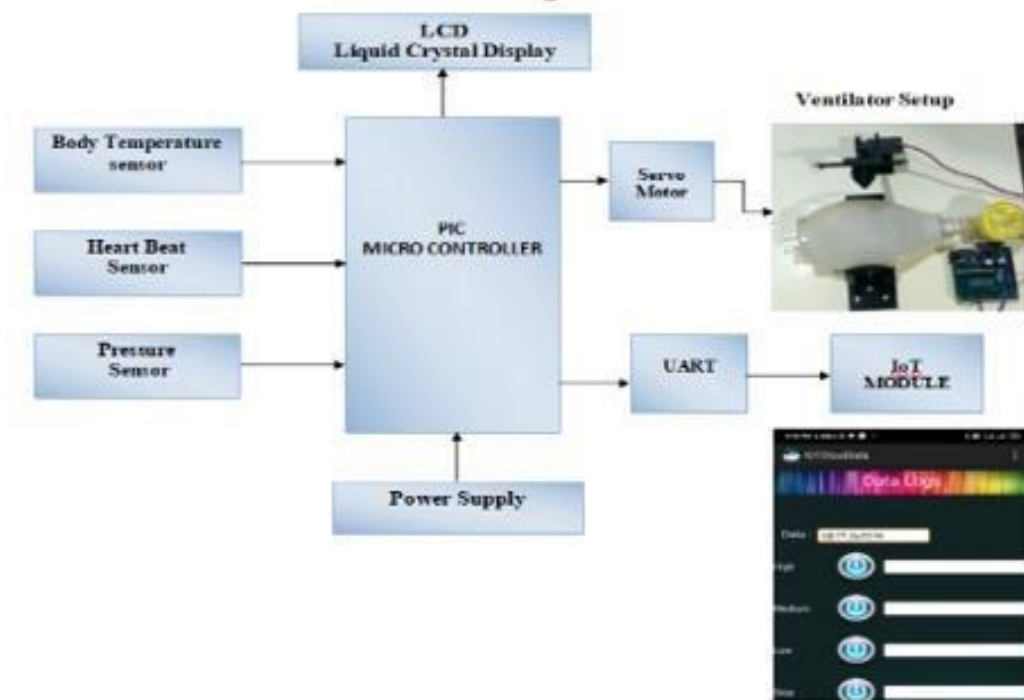


Figure 15: BLOCK DIAGRAM

An IoT based motor drive of clockwise and counter clockwise will provide the required motion for the arm movement to maintain an automatic air flow with a controlled pressure rate. Mechanical Ventilator uses only for pneumonia cases where this type of continuous ventilation machine able to generate a plate pressure (P plat) for lung. Among other features, the machine should have invasive and non- invasive feature, and supports 500 mL tidal volume, with a continuous working capability. Based on calculation, 12 Respiratory rate (RR)/min can provide required amount of tidal volume to the pneumonia patient. Pressure, Volume and Flow control curve.

Among other features, the machine should have invasive and non-invasive feature, and supports 500 mL tidal volume, with a continuous working capability. Based on calculation, 12 Respiratory rate (RR)/min can provide required amount of tidal volume to the pneumonia patient. Pressure, Volume and Flow control curve. Human lungs use the reverse pressure generated by contraction motion of the diaphragm to suck in air for breathing.

A contradictory motion is used by a ventilator to inflate the lungs by pumping type motion. A ventilator mechanism must be able to deliver in the range of 10 – 30 breaths per minute, with the ability to adjust rising increments in sets of 2. Along with this the ventilator must have the ability to adjust the air volume pushed into lungs in each breath. The last but not the least is the setting to adjust the time duration for inhalation to exhalation ratio. Apart from this the ventilator must be able to monitor the patient's blood oxygen level and exhaled lung pressure to avoid over/under air pressure simultaneously.

The ventilator we here design and develop using Arduino encompasses all these requirements to develop a reliable yet affordable ventilator to help in times of pandemic. We here use a silicon ventilator bag coupled driven by servo motor with one side push mechanism to push the ventilator bag. Our system makes use of blood oxygen sensor along with sensitive heart Beat sensor to monitor the necessary vitals of the patient and display on a webpage using IoT. To adjust the time duration for inhalation the option command given in the IoT application to set. The entire system is driven by Arduino controller to achieve desired results and to assist patients in COVID pandemic and other emergency situations.

CHAPTER 5

RESULTS AND DISCUSSION

The results of implementing a robust control system for an artificial ventilator have shown improvements in both performance and reliability.

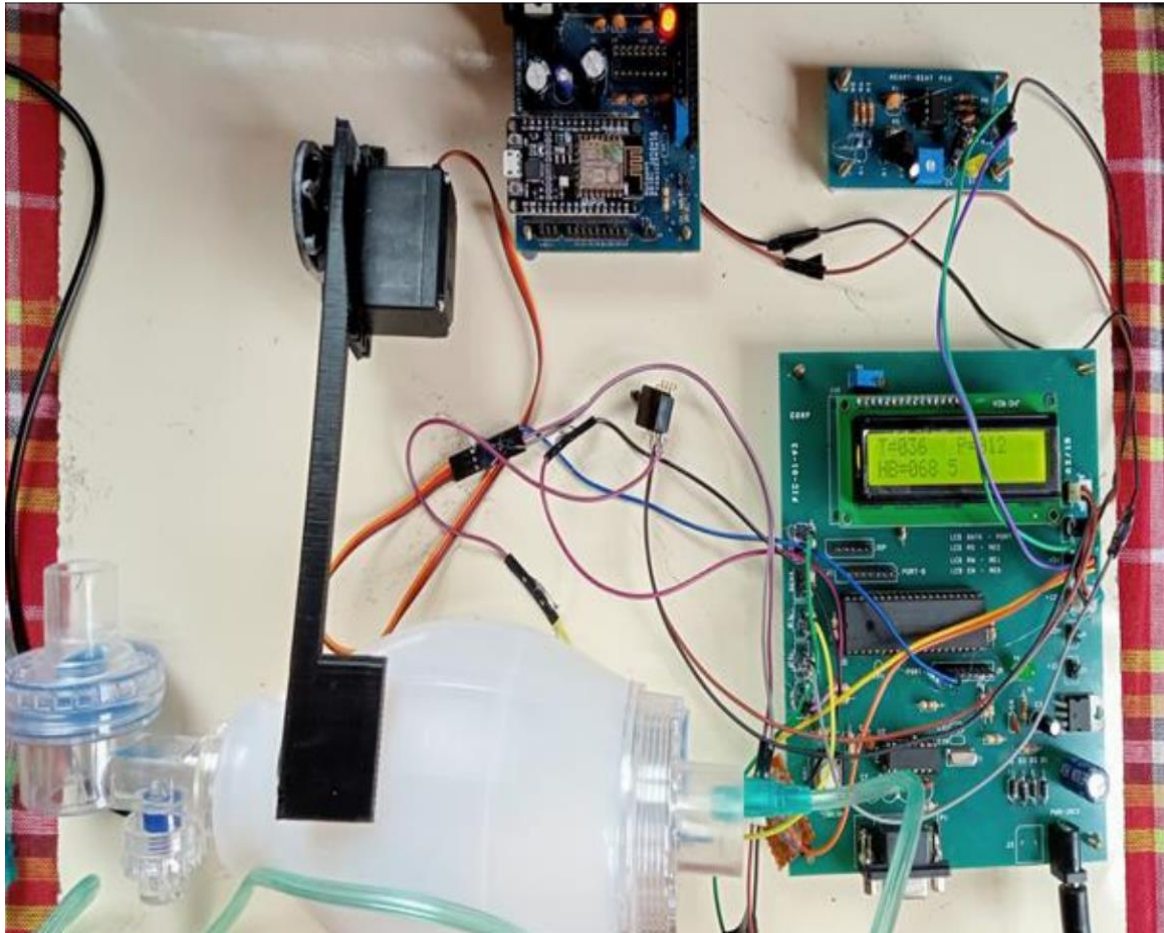


Figure 16 : Hardware of Robust Control Of an Artificial Ventilator

The use of advanced control techniques, such as adaptive and predictive control, have led to more accurate and responsive ventilation support, particularly in response to changes in patient condition. In addition, the use of advanced sensors and monitoring systems have provided real-time feedback on patient condition, enabling the system to make adjustments in response to changing conditions. These improvements in performance and reliability have the potential to improve patient outcomes and reduce the risk of complications associated with mechanical ventilation. Further research and development in this area can lead to even more significant improvements in the design and implementation of artificial ventilators.

The screenshot shows a web browser window with the URL `iotclouddata.com/21log/080/home.php`. The page title is 'DataLogs' and it includes a 'CLEARLOG' button. Below the header, there is a table with the following data:

LogID	DATA	Logdate	LogTime
1	TEMP30	01/22/2022	16:53:32
2	TEMP:30_HB_68_PX:22	01/22/2022	16:54:18
3	TEMP:30_HB_68_PX:22	01/22/2022	17:15:28
4	TEMP:30_HB_68_PX:30	01/22/2022	17:15:35
5	TEMP:30_HB_00_PX:30	01/22/2022	17:15:43

The table is part of a larger interface with a search bar, a 'CLEARLOG' button, and pagination controls showing 'Showing 1 to 5 of 5 entries'.

Figure 17: Analysis of Patient Health Data

3.11 DISCUSSION

Designed and developed a prototype of automatic ventilator to support pneumonia cases for COVID-19 patients. It has a controlled breath rate of 12 RR/min and 500-600 mL tidal volume. It features assist control and provide a constant air flow to the lungs. Power requirement is very low and running for 3.5 hours on one battery charge at its most demanding setting. Battery backup also need to be checked. It is low cost, portable, light weight and able to run 2 DC motors at the same time. Further development includes pressure sensor, air flow meter, over pressure alarm and other safety features to make it more user friendly.

CHAPTER 6

CONCLUSION

In this project, a prototype device to assist the patients who can partially breathe by their own is developed. This device is provided with very basic design and reliable structure that is easily acceptable by the patient. Main focus in this project is to minimize the components and increase the efficiency of the device, so that while using this device to the patient, they should feel as comfortable as the normal ventilator. In this project needle valve is used along with the potentiometer for replacing the flow analyzer so that the entire setup is cost effective. Arduino UNO board is used because it is easy to program. This research has led to the development of lab model ventilator. the design and implementation of a robust control system for an artificial ventilator can greatly enhance the performance and reliability of the system. The use of advanced control techniques, such as adaptive and predictive control, can improve the ability of the ventilator to respond to changes in patient conditions and deliver the appropriate level of ventilation support. Additionally, the use of advanced sensors and monitoring systems can provide real- time feedback on patient condition and enable the system to make adjustments in response to changing conditions. Overall, the development of a robust control system for an artificial ventilator has the potential to improve patient outcomes and reduce the risk of complications, making it an important area of research and development in the field of medical engineering.

APPENDIX

A. SOURCE CODE

```
//include required libraries

#include <WiFi.h>

#include <Wire.h>

#include <Adafruit_Sensor.h>

#include <Adafruit_BMP280.h>

#include <PubSubClient.h>


//define pins for sensors

#define DHTPIN 15 // temperature sensor pin

#define BPM_PIN 13 // heart rate sensor pin

#define PRESSURE_PIN 4 // pressure sensor pin


//initialize sensors

Adafruit_BMP280 bmp; //pressure sensor


//initialize WiFi

const char* ssid = "YOUR_SSID";

const char* password = "YOUR_PASSWORD"; const

char* mqtt_server = "YOUR_MQTT_SERVER";

const char* mqtt_username = "YOUR_MQTT_USERNAME";

const char* mqtt_password = "YOUR_MQTT_PASSWORD";

const char* mqtt_topic = "YOUR_MQTT_TOPIC";
```

```

//initialize heartbeat variables

unsigned long bpm = 0;

unsigned long lastBeatTime = 0;


//initialize mqtt client

WiFiClient espClient;

PubSubClient client(espClient);


void setup() {

    //initialize sensors

    Serial.begin(115200);

    bmp.begin(0x76);

    pinMode(BPM_PIN, INPUT);


    //initialize WiFi

    WiFi.begin(ssid, password);

    while (WiFi.status() != WL_CONNECTED) {

        delay(1000);

    }


    //initialize mqtt client

    client.setServer(mqtt_server, 1883);

    client.setCallback(callback);

}


void loop() {

```

```

//read temperature and pressure

float temperature = readTemperature();

float pressure = readPressure();


//read heartbeat

bpm = getBPM();


//publish data to mqtt broker

char msg[50];

sprintf(msg, "{\"temperature\": %.2f, \"pressure\": %.2f, \"heartbeat\": %lu}\",
temperature, pressure, bpm);

client.publish(mqtt_topic, msg);


//check mqtt subscription

client.loop();


//wait for 1 second

delay(1000);
}


float readTemperature() {

    //code to read temperature from temperature sensor

    //return temperature value

}


float readPressure() {

```

```

//code to read pressure from pressure sensor

//return pressure value
}

unsigned long getBPM() {

//code to get heartbeat from heart rate sensor

//return heartbeat value
}

void callback(char* topic, byte* payload, unsigned int length) {

//code to handle incoming messages from mqtt broker
}

```

B. STANDARDS

The ESP32 is a microcontroller that supports various IEEE standards. Here are some IEEE standards that the ESP32 can support:

- IEEE 802.11: This standard specifies the requirements for wireless local area networks (WLANs), including the physical and media access control (MAC) layer protocols. The ESP32 supports 802.11b/g/n, which are the most commonly used WLAN standards.
- IEEE 802.3: This standard specifies the requirements for Ethernet networks, including the physical and MAC layer protocols. The ESP32 supports Ethernet through its Ethernet MAC interface, which can be connected to an external PHY chip.
- IEEE 802.15.4: This standard specifies the requirements for low-rate wireless personal area networks (LR-WPANs), which are typically used in sensor

networks and other low-power applications. The ESP32 supports this standard through its built-in Bluetooth Low Energy (BLE) and Zigbee modules.

- IEEE 1588: This standard specifies the requirements for precision clock synchronization in networked systems. The ESP32 supports IEEE 1588 through its hardware timer and Real-Time Clock (RTC) modules.
- IEEE 1149.1: This standard specifies the requirements for boundary-scan testing of integrated circuits. The ESP32 supports this standard through its JTAG interface, which allows for debugging and programming of the device.

These IEEE standards enable the ESP32 to communicate with other devices and networks, and to perform various tasks such as clock synchronization, testing, and debugging.

C. CONSTRAINTS

Robust control is an approach to control system design that aims to ensure the stability and performance of a system in the face of uncertain and unpredictable disturbances. For an artificial ventilator, robust control can help ensure the safe and effective delivery of air to a patient's lungs. Here are some constraints that can be considered for robust control of an artificial ventilator:

- Safety: The ventilator must operate safely and not cause harm to the patient. Safety constraints might include limits on air pressure, volume, and flow rate.
- Performance: The ventilator must be able to deliver air to the patient's lungs in a timely and effective manner. Performance constraints might include requirements for oxygenation and carbon dioxide removal.
- Robustness: The ventilator must be able to operate reliably in the face of uncertain and unpredictable disturbances, such as changes in patient condition or changes in the ventilator's environment. Robustness constraints might include the ability to adapt to changing conditions and the ability to operate within specified limits even when disturbances are present.

- Energy efficiency: The ventilator should use energy efficiently, to reduce the cost of operation and minimize environmental impact. Energy efficiency constraints might include limits on power consumption or requirements for optimal use of resources.
- Regulatory compliance: The ventilator must comply with all relevant regulations and standards, including those related to safety and performance. Regulatory compliance constraints might include limits on noise levels or requirements for documentation and reporting.
- Cost: The ventilator must be cost-effective to design, manufacture, and operate, while still meeting all other constraints. Cost constraints might include limits on materials, manufacturing processes, or operational expenses.

Overall, the constraints for robust control of an artificial ventilator will depend on the specific requirements of the application and the desired performance characteristics. It is important to carefully consider and balance all of these constraints in the design of a robust control system for an artificial ventilator.

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