VISVESVARAYA TECHNOLOGICAL UNIVERSITY

BELAGAVI, KARNATAKA

PROJECT (20ECP83)

Report on

"LOW COST VENTILATOR"

Submitted in the partial fulfillment for the award of bachelor degree in Electronics and Communication Engineering

Submitted by

AKASH J	**1GA20EC010**
ASWIN JAYADASAN	**1GA20EC025**
CHANDAN P	**1GA20EC032**

Under the Guidance of

KRUTHIK CHAND D C

Department of Electronics and Communication Engineering

Global Academy of Technology

BENGALURU – 560098

2023-2024

GLOBAL ACADEMY OF TECHNOLOGY

RAJARAJESHWARI NAGAR, BENGALURU-560098

NAAC – 'A' Grade and NBA Accreditated

Department of Electronics and Communications Engineering

CERTIFICATE

Certified that the project (20ECP83) entitled

"LOW COST VENTILATOR"

Carried out by,

AKASH J	**1GA20EC010**
ASWIN JAYADASAN	**1GA20EC025**
CHANDAN P	**1GA20EC032**

Bonafide students of Global Academy of Technology in partial fulfillment for the award of Bachelor of Engineering in Electronics and Communication Engineering of the Visvesvaraya Technological University, Belagavi during the academic year 2023-24. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report deposited in the Departmental library. The project report has been approved as it satisfies the academic requirements in respect of project work prescribed for the said Degree.

Signature of the Guide	Signature of the HOD	Signature of the Principal
[Kruthik Chand D C]	[Dr. Manjunatha Reddy H S]	[Dr. Ranapratap Reddy N]

External Viva

Name of the examiners **Signature with date**

1.
2.

TABLE OF CONTENT

CHAPTER - 1

Introduction

1.1 Introduction

Ventilators are one of the most important devices to keep COVID-19 patients in the most critical condition alive. As the global demand for ventilators is increasing and there is shortage of ventilators in our country as well, also managing patients during this time is a big task, so we have designed portable automatic Ambu bag operating device for low-cost ventilator, which will help people in this pandemic.

During health crises such as the COVID-19 pandemic, there was a global shortage of ventilators. Low-cost alternatives, like those based on Arduino, can be quickly developed and deployed in emergency situations to supplement existing healthcare infrastructure. In many parts of the world, especially in developing countries and rural areas, access to expensive medical equipment like traditional ventilators is limited. Low-cost ventilators can bridge this accessibility gap, making life-saving respiratory support more widely available.

A low-cost ventilator is designed to provide life-saving respiratory support at an affordable price. These devices aim to address global healthcare challenges by making critical medical technology more accessible, especially in resource-constrained settings. By leveraging cost-effective components and streamlined design, they offer a practical solution to enhance ventilatory care, particularly during emergencies or in regions with limited healthcare infrastructure.

In resource-constrained settings and during global health crises, the significance of affordable ventilators becomes even more apparent. These devices offer a lifeline to patients in need, serving as a reliable and cost-efficient solution to respiratory challenges. The low-cost ventilator's portability and simplicity make it an invaluable tool, capable of deployment in diverse environments, from remote healthcare facilities to emergency response scenarios.

1.2 Problem Definition

The problem statement for developing a low-cost ventilator is rooted in the global need for affordable and accessible healthcare solutions, particularly in resource-constrained environments. Traditional ventilators are often expensive and complex, posing challenges for widespread adoption, especially in developing countries or during healthcare crises. The high cost of conventional ventilators limits their availability in areas with limited financial resources, hindering the ability to provide life-saving respiratory support.

- Affordability: Designing a ventilator that is both effective and affordable for healthcare facilities with limited budgets.
- Resource Constraints: Developing a ventilator that can operate efficiently with limited power sources, such as in remote or resource-constrained areas.
- Availability of Parts: Finding alternative, readily available components that can be used to build low-cost ventilators, as some critical components may be scarce or expensive.
- Monitoring and Data Collection: Incorporating features for real-time patient monitoring and data collection, which can aid in treatment and research efforts.
- During health crises such as the COVID-19 pandemic, there was a global shortage of ventilators. In many parts of the world, especially in developing countries and rural areas, access to expensive medical equipment like traditional ventilators is limited

CHAPTER – 2

LITERATURE SURVEY

[1] **CAIO ARAUJO DAMASCENO;AYLSON LOPES LEAL;GABRYEL FIGUEIREDO SOARES;GUSTAVO RETUCI PINHEIRO;LUAN DA SILVA BEZERRA;MATHEUS DE CASTRO PASSOS PRADO;YASMIN MARTINS PERCI;Miguel Neto*; (2021). Low cost volume sensors for mechanical ventilators . IEEE Latin America Transactions, (), –. doi:10.1109/TLA.2021.9451255***

This paper presents and compares three volume sensors to be used in mechanical ventilators developed in laboratory: volume sensor based on the Pitot tube, volume sensor based on the Venturi tube and infrared(IR) volume sensor. The three sensors were calibrated and tested with a mechanical ventilator in Pressure-controlled Ventilation (PCV) mode. The maximum pressure changed, keeping Positive End-Expiratory Pressure (PEEP) and respiratory rate fixed

[2] **Bharucha, Eric; Gosselin, Benoit; Lellouche, Francois (2020). [IEEE 2020 18th IEEE International New Circuits and Systems Conference (NEWCAS) - MontrÃ©al, QC, Canada (2020.6.16-2020.6.19)] 2020 18th IEEE International New Circuits and Systems Conference (NEWCAS) - *A Long-Lifetime, Low-Cost Self-Tuning Patch Oximeter for Ventilation Therapy., (), 327–330. doi:10.1109/NEWCAS49341.2020.9159759***

This paper describes a new patch oximeter architecture that automatically selects the best sampling site within a patch array of sensors. This array allows for non-obtrusive chronic care. Sensor triads composed of 2 emitters and a photoreceptor are laid out on a surface that, with the aid of a microcontroller, automatically selects the best signal amplitude domain available on the skin. The data is slated for use with oxygen therapy and ventilators. We show, not only that we can extract pulse, oximetric data with clinical value, but also improved longevity of such devices, making the design practical in a variety of clinical setting

[3] **Islam, Md. Rakibul; Ahmad, Mohiuddin; Hossain, Md. Shahin; Muinul Islam, Muhammad; Uddin Ahmed, Sk. Farid (2019). [IEEE 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT) - Dhaka, Bangladesh (2019.5.3-2019.5.5)] 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT) -** ***Designing an Electro-Mechanical Ventilator Based on Double CAM Integration Mechanism. , (), 1–6. doi:10.1109/ICASERT.2019.8934562***

This paper proposes a simplified structure of microcontroller based mechanical ventilator integrated with a Bag-Valve-Musk (BVM) ventilation mechanism. Here, an Ambu bag is operated with computer-aided manufacturing (CAM) arm that is commanded via a microcontroller and manual switches by sending a control signal to the mechanical system and according to this control signal, the mechanical computer-aided manufacturing (CAM) arm simultaneously compresses and decompresses the Ambu bag. It is a self-inflating bag and like a one-way valve around its inlet and outlet corner

[4] **Ramos-Paz, Serafin; Belmonte-Izquierdo, Ruben; Inostroza-Moreno, Luis Alfonso; Velasco-Rivera, Luisa Fernanda; Mendoza-Villa, Ricardo; Gaona-Flores, Valeria (2020*). [IEEE 2020 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC) - Ixtapa, Mexico (2020.11.4-2020.11.6)]* 2020 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC) -** ***Mechatronic Design and Robust Control of an Artificial Ventilator in Response to the COVID-19 Pandemic. doi:10.1109/ropec50909.2020.9258736***

The crisis resulting from the COVID-19 pandemic has generated an adverse situation in which thousands of people dies due to the lack of artificial ventilation devices. In this sense, this work presents a proposal for the robust mechatronic design and control of a low-cost non-invasive ventilator, for which rapid prototyping manufacture strategies such as 3D printing and product design are used.

[5] **Qing Arn Ng;Yeong Shiong Chiew;Xin Wang;Chee Pin Tan;Mohd Basri Mat Nor;Nor Salwa Damanhuri;J. Geoffrey Chase; (2021). Network Data Acquisition and Monitoring System for Intensive *Care Mechanical Ventilation Treatment* . *IEEE Access, doi:10.1109/access.2021.3092194***

The rise of model-based and machine learning methods have created increasingly realistic opportunities to implement personalized, patient-specific mechanical ventilation (MV) in the ICU. These methods require monitoring of real-time patient ventilation waveform data (VWD) during MV treatment. However, there are relatively few non-invasive and/or non-proprietary systems to monitor and record patient-specific lung condition in real-time.

[6] **Md. Rakibul Islam;Mohiuddin Ahmad;Md. Shahin Hossain;Muhammad Muinul Islam;Sk. Farid Uddin Ahmed; (2020). Designing and Prototyping of an Electromechanical Ventilator based on Double CAM operation Integrated with Telemedicine Application . *2020 IEEE Region 10 Symposium (TENSYMP), (), – . doi:10.1109/TENSYMP50017.2020.9230673***

In this paper, we proposed to design a new model of mechanical ventilator based on the Ambu bag automation for the patient who is unable to take breath normally. Here we have automated an Ambu bag for air supply whose inlet is connected with an oxygen cylinder and environmental air and outlet is connected to lung patient. The project device includes a robotic operator which can operate an Ambu bag continuously by compressing and decompressing it.

[7] **Govoni, L; Farre, R; Pedotti, A; Montserrat, J M; Dellaca, R L (2010). [IEEE 2010 5th Cairo International Biomedical Engineering Conference (CIBEC 2010) - Cairo (2010.12.16-2010.12.18)] 2010 5th Cairo International Biomedical Engineering Conference - *An improved telemedicine system for remote titration and optimization of Home Mechanical Ventilation. , (), 66–69. doi:10.1109/cibec.2010.5716060***

Home Mechanical Ventilation is applied to patients with different chronic respiratory diseases and, in order to be effective, it requires accurate individual titration. Nowadays this can be obtained only in the hospital during day or night visits, and this is associated with long waiting lists and high costs.

[8] **Calilung, E., Espanola, J., Dadios, E., Culaba, A., Sybingco, E., Bandala, A., … Castillo, C. J. P. (2020). Design and Development of an Automated Compression Mechanism for a Bag-Valve-Mask-Based Emergency Ventilator. 2020 IEEE 12th International Conference on Humanoid, Nanotechnology,** ***Information Technology, Communication and Control, Environment, and Management (HNICEM). doi:10.1109/hnicem51456.2020.9400150***

In response to COVID-19 pandemic ,universities and related institutions around the world came up with various mechanical ventilator designs to help cope with the expected shortages of ventilators as the pandemic rages. Many of these designs are based on automating the manual operation of the Bag Valve Mask (BVM), a ubiquitous resuscitator device used for emergency ventilation or resuscitation of patients with breathing problems. In this paper, the mechanical design and development process for a BVM-based emergency ventilator is discussed. In particular, the evolution of the design from a simple, low-cost device to a more sophisticated system acceptable to pulmonologists and related medical practitioners is documented.

[9] **Zhang, Y., Zhao, L., Yang, K., & Xu, L. (2020). Mobile Edge Computing for Intelligent Mining Safety: A Case Study of Ventilator. 2020 IEEE Intl Conf on Parallel & Distributed Processing with Applications, Big Data & Cloud Computing, Sustainable Computing & Communications, Social Computing & Networking(ISPA/BDCloud/SocialCom/SustainCom*).https://doi.org/10.1109/ispa-bdcloud-socialcom-sustaincom51426.2020.00192 doi:10.1109/ISPA-BDCloud-SocialCom-SustainCom51426.2020.00192***

The underground mining field sometimes is uncertain, which may lead to the severity of incidents, including explosion, corruption, and toxic air. To this end, it is vital to monitor and analyze the possibility of incidents and promote the corresponding rescue actions. It is still challenging to realize real- time data processing, in which the deployment of large computing devices is facing problems, including energy, space, and surrounding dusty environment. Besides, due to the complex environment, transmitting the collected data to the remote cloud can suffer from the inevitable high latency under the current communication technology, in which suffer. By bringing the server to the location closed to the miner, mobile edge computing (MEC) is a promising distributed computation architecture to seize the opportunity of enabling low-cost, low-latency collection and processing. In the underground mining field, miners' life status should be monitored in real-time. In this context, MEC is a right candidate for such a scenario. In this paper, we discuss the utilization of MEC for analysing miner's body condition. We also show the challenges and open issues of such an application. Also, we give a case study of using MEC-enabled miner health platform to assist the ventilator in the underground field

[10] **Lazzaro, N., Giannella, A., & Panerai, R. B. (1992). Clinical engineering and the quality of health care: The feasibility of low cost interventions. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society. doi:10.1109/iembs.1992.5761394***

A method was developed to select clinical engineering interventions which can address specific problems of quality of care in a hospital. Emphasis is placed on low cost interventions which can demonstrate the potential of clinical engineering for developing countries. The utilization of mechanical ventilators (MV)was selected as a representative quality of care problem in a 650 bed teaching hospital. The application of the methodology developed led to the selection of an educational intervention which was shown to be effective($p < 0.001$) for reducing the chronic problems observed with the utilization of MV.

CHAPTER – 3

METHODOLOGY

3.1 Methodology

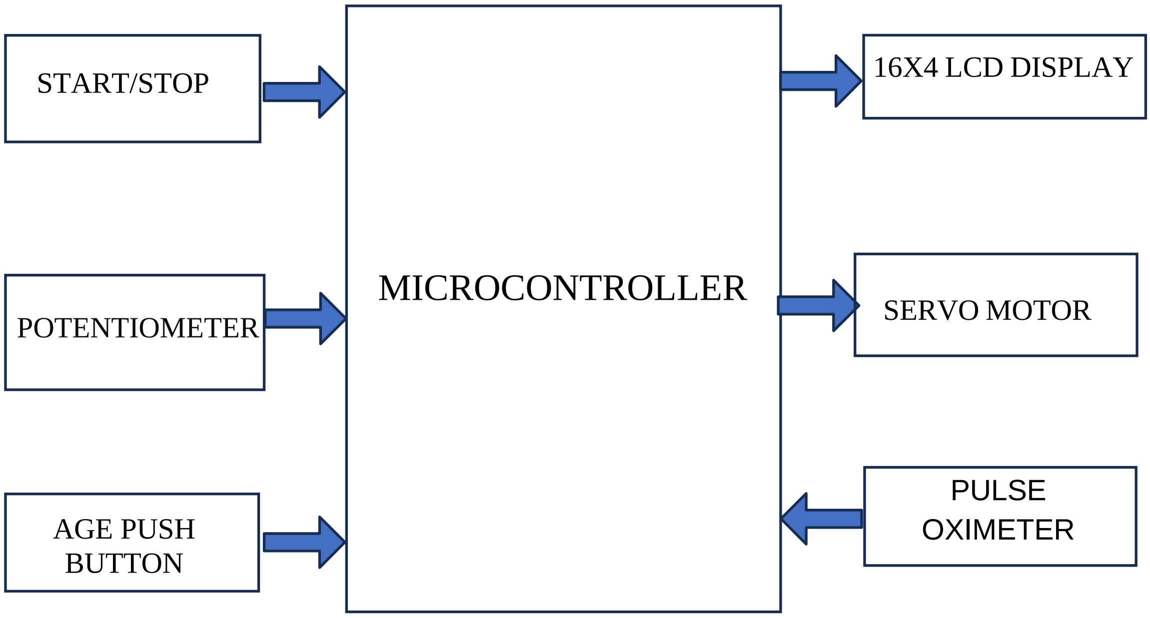

Figure 3.1: Block Diagram

The Arduino microcontroller, acting as the central control unit. Arduino gets the values from the potentiometer and provides it to the LCD and the values are displayed on the lcd .Intialially when the push button (start/stop button) is pressed then the system gets started and Arduino does the computation of calculating the angle, speed of servo motor and also the timing between squeeze and release and provide it to the servo motor. Servo motor starts rotating accordingly.

A low-cost ventilator is a vital medical device designed to provide mechanical respiratory support to patients, particularly in situations where traditional ventilators may be unavailable or prohibitively expensive. The block diagram below outlines the essential components of such a system .

Ambu Bag or Manual Resuscitator: At the core of the ventilator is the Ambu bag, a self-expanding bag that can be manually compressed to deliver positive pressure ventilation to the patient. This component ensures the basic mechanism for air delivery.

Flow Control Valve: Positioned in the airflow path, this valve regulates the volume and rate of air delivered to the patient. Precise control is crucial to tailor ventilation to the patient's needs.

Pressure Sensor: Monitoring airway pressure is crucial to prevent potential harm to the patient. The pressure sensor provides feedback to the system, allowing it to adjust ventilation parameters to maintain safe levels.

Microcontroller: Serving as the brain of the system, the microcontroller processes input from sensors and translates it into specific control signals. It governs the timing and duration of ventilation cycles, ensuring synchronization with the patient's respiratory needs .

Oxygen Source: An additional oxygen source, controlled by a valve, supplements the air mixture if necessary. This ensures that the patient receives an appropriate oxygen concentration, especially critical for those with respiratory distress.

Display and Controls: The user interface provides a means for healthcare professionals to set ventilation parameters and monitor crucial information. This user-friendly aspect facilitates effective and precise adjustments based on the patient's condition .

Alarm System: An integral safety feature, the alarm system detects and alerts medical staff to potential issues such as low oxygen levels, high airway pressure, or other malfunctions. This ensures timely intervention and patient safety.

Documentation is key for replication and regulatory compliance. Share the design openly to encourage collaboration and widespread production. Regularly update the design based on user feedback and emerging technologies. This iterative process ensures continuous improvement in creating an affordable and effective ventilator.

3.2 Process Flow Chart

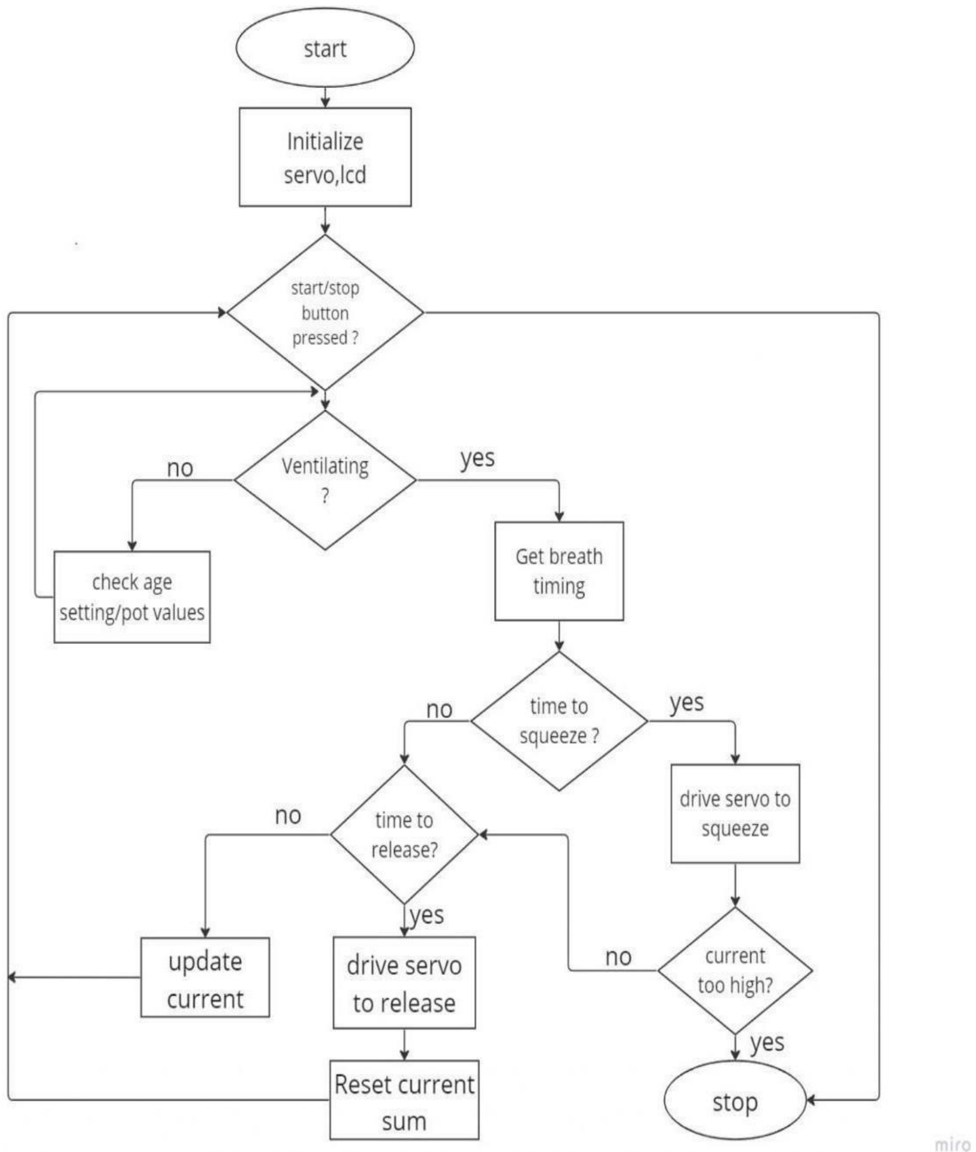

Figure 3.2: Flow chart

The system is initialized by setting up serial communication, configuring pins for LEDs, buttons, servo motor, and initializing the LCD display. The red and green LEDs are briefly turned on, and the LCD is initialized with startup messages. he main loop continuously checksand performs various tasks based on conditions.

The code checks for button presses, specifically the age button and start/stop button. If the agebutton is pressed, the age display on the LCD is updated. If the start/stop button is pressed, thecode toggles the ventilating state. If the system is ventilating, the code calculates the servo delay and controls the servo motor accordingly. It checks for specific conditions to determine when to squeeze (compress) and release during the ventilation process. The code includes safety checks, such as monitoring the current sensor. If the current is too high (indicating a potential issue for an adult patient), the system is halted, the green LED is turned off, and a warning flag is set. The red LED flashes if there's a warning or issue with the ventilation process. The green LED indicates the ventilating state. The servo motor is controlled to moveto specific positions based on the ventilation process stages.

The LCD is continuously updated to display information about the age group, potentiometer values, and other relevant parameters. The halt variable is used to control the halting of the ventilator under certain conditions, ensuring patient safety. The main loop continues to executethese tasks until the program is stopped or interrupted.

Throughout this process, sensors monitor variables like pressure and flow rate, providing feedback to the control system for real-time adjustments. Lastly, an exhaust valve releases exhaled air, completing the cycle. This simplified yet effective flow chart allows for the creation of affordable ventilators, crucial in resource-constrained environments or during health crises when widespread access to respiratory support is essential.

3.3. Figures of Components

3.3.1 Hardware

1. NODEMCU ESP8266

Figure.3.5.1: ESP 8266

- Integrated Wi-Fi module for easy internet connectivity.
- Supports multiple programming environments such as Arduino IDE, Lua, and MicroPython.
- Several General Purpose Input/Output (GPIO) pins for interfacing with sensors and actuators.
- Affordable option for IoT projects, suitable for hobbyists, students, and professionals.
- Extensive community support with numerous online resources, tutorials, and libraries.

MAX30100(integrated pulse oximetry and heart- rate monitor sensor)

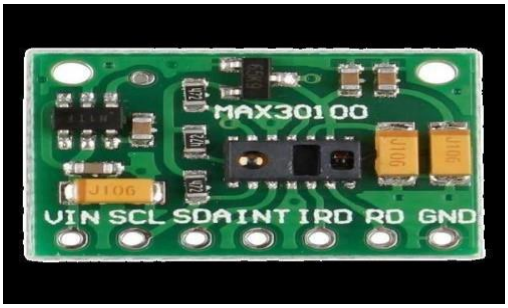

Figure.3.5.2: Pulse oximeter

- It combines two LEDs
- photodetector

- optimized optics
- low-noise analog signal processing to detect pulse oximetry and heart-rate signals.

2. SERVO MOTOR

Figure.3.5.3: Servo motor

- RPM: 0.20s/60 degrees (4.8V), 0.16s/60 degrees (6V)
- Voltage: 4.8V - 6.6V.
- Torque: 9.4kg/cm (4.8V) - 11kg/cm (6V)
- Angle: 180 degrees
- Weight: 55g.

3. AMBU BAG

Figure 3.5.4: Ambu Bag

- Adult fixture is equipped with a mask, a tank of oxygen with a volume of 1800 ml bag1500 ml In this mixture out in a volume of ml. 800-1350 Dead zone is 168 ml., the Device is designed 45BPM compressions per minute

- For children the mask of the third size is used. The volume of the oxygen tank is 750 ml, the volume of the bag is 550 ml, the air mixture comes out in a volume of 350 ml. the Dead space is 113 ml. the Device is designed for a maximum compression per minute of 105BPM.

3.6 Software

ARDUINO IDE

Figure 3.6.1: Arduino IDE Logo

3.7. Components description

NODEMCU ESP8266

The ESP8266 NodeMCU is a highly versatile and cost-effective module widely used in IoT projects. It features an integrated Wi-Fi module, simplifying the process of connecting devices to the internet. This module supports multiple programming environments, including the Arduino IDE, Lua, and MicroPython, offering developers flexibility in their coding preferences. With several General Purpose Input/Output (GPIO) pins, the NodeMCU can easily interface with various sensors and actuators, making it suitable for a wide range of applications. Its affordability makes it accessible to hobbyists, students, and professionals alike. Additionally, the extensive community support and abundance of online resources, tutorials, and libraries make development and troubleshooting straightforward, contributing to its popularity in the tech community.

MAX30100(integrated pulse oximetry and heart- rate monitor sensor)

The MAX30100 is a versatile sensor module designed for integrated pulse oximetry and heart-rate monitoring, offering a compact and efficient solution for health monitoring applications. Equipped with both red and infrared LEDs, this sensor leverages photodetectors to measure the absorption of light by the user's blood, enabling accurate and real-time assessments of vital signs.

One of the primary functionalities of the MAX30100 is pulse oximetry, a crucial metric for evaluating blood oxygen saturation levels. By utilizing the dual-LED configuration, the sensor can differentiate between the absorption of red and infrared light, providing valuable insights into the oxygen content in the bloodstream. This capability is particularly essential for assessing respiratory health and ensuring an adequate supply of oxygen to the body's tissues.

In addition to pulse oximetry, the MAX30100 excels in heart-rate monitoring. The sensor detects the pulsatile nature of blood flow, allowing for the precise measurement of the user's heart rate. This makes the MAX30100 an ideal component for applications such as fitness trackers, smartwatches, and other wearable devices focused on continuous health monitoring.

SERVO MOTOR

To enhance the reliability of servo motors, some systems implement fail-safe mechanisms. These mechanisms could include position feedback redundancy or the incorporation of limit switches to prevent the motor from overtravel, ensuring the longevity of both the motor and the tracking system. Moreover, servo motors with ability to enter low-power modes during periods of inactivity.

AMBU BAG

The Ambu bag, or bag-valve-mask (BVM) resuscitator, is a crucial medical device employed in emergency situations to provide manual positive pressure ventilation to individuals experiencing respiratory distress or failure. Consisting of a self-expanding bag, non-rebreathing valve, and a facial mask, the Ambu bag allows healthcare professionals to manually deliver breaths to a patient's lungs.

3.8 SOFTWARE ARCHITECTURE

3.8.1 Software requirements

1. Proteus ISIS [System Design]

The Proteus Design Suite is an Electronic Design Automation (EDA) tool including schematic capture, simulation and PCB Layout modules. It is developed in Yorkshire, England by Lab centre Electronics Ltd with offices in North America and several overseas sales channels. The software runs on the Windows operating system. The micro-controller simulation in Proteus works by applying either a hex file or a debug file to the microcontroller part on the schematic. It is then co- simulated along with any analog and digital electronics connected to it. This enables it's used in a broad spectrum of project prototyping in areas such as motor control, temperature control and user interface design.

2. Arduino IDE

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

CHAPTER 4

CONCLUSION

The project demonstrates a well-thought-out user interface with potentiometers for user input, an LCD display for feedback, and buttons for age group selection and system control. Safety features, including warning LEDs and the ability to halt the system under certain conditions, enhance the reliability of the ventilator. The servo motor, used for controlling the inhalation/exhalation process, is intricately managed based on user-defined settings. The incorporation of current sensing adds an additional layer of safety and monitoring to the system. The project's focus on age-specific settings and the inclusion of safety measures reflects a thoughtful consideration of diverse patient needs.

The impact of low-cost ventilators extends beyond their immediate use; they represent a paradigm shift in healthcare equity. The affordability factor facilitates mass production, distribution, and deployment, thereby ensuring that even resource-constrained communities can access life-saving technology. This democratization of medical resources not only addresses current challenges, such as the COVID-19 pandemic, but also establishes a resilient foundation for future healthcare crises.As we celebrate the success of low-cost ventilators, it is crucial to sustain this momentum in medical innovation. Continued research, collaboration, and investment in such solutions promise a brighter and healthier future, where life-saving technologies are not confined by economic constraints. In essence, the era of low-cost ventilators signifies a transformative stride towards inclusive and accessible healthcare on a global scale.

REFERENCES

*[1]*CAIO ARAUJO DAMASCENO;AYLSON LOPES LEAL;GABRYEL FIGUEIREDO SOARES;GUSTAVO RETUCI PINHEIRO;LUAN DA SILVA BEZERRA;MATHEUS DE CASTRO PASSOS PRADO;YASMIN MARTINS PERCI;Miguel Neto*; (2021). Low cost volume sensors for mechanical ventilators . IEEE Latin America Transactions, (), –. doi:10.1109/TLA.2021.9451255*

[2] Bharucha, Eric; Gosselin, Benoit; Lellouche, Francois (2020). [IEEE 2020 18th IEEE International New Circuits and Systems Conference (NEWCAS) - MontrÃ©al, QC, Canada (2020.6.16-2020.6.19)] 2020 18th IEEE International New Circuits and Systems Conference (NEWCAS) - *A Long-Lifetime, Low-Cost Self-Tuning Patch Oximeter for Ventilation Therapy. , (), 327–330. doi:10.1109/NEWCAS49341.2020.9159759*

[3] Islam, Md. Rakibul; Ahmad, Mohiuddin; Hossain, Md. Shahin; Muinul Islam, Muhammad; Uddin Ahmed, Sk. Farid (2019). [IEEE 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT) - Dhaka, Bangladesh (2019.5.3-2019.5.5)] 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT) - *Designing an Electro-Mechanical Ventilator Based on Double CAM Integration Mechanism. , (), 1–6. doi:10.1109/ICASERT.2019.8934562*

[4] Ramos-Paz, Serafin; Belmonte-Izquierdo, Ruben; Inostroza-Moreno, Luis Alfonso; Velasco-Rivera, Luisa Fernanda; Mendoza-Villa, Ricardo; Gaona-Flores, Valeria (2020*). [IEEE 2020 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC) - Ixtapa, Mexico (2020.11.4-2020.11.6)]* 2020 IEEE International Autumn Meeting on Power, Electronics and Computing (ROPEC) - *Mechatronic Design and Robust Control of an Artificial Ventilator in Response to the COVID-19 Pandemic. doi:10.1109/ropec50909.2020.9258736*

[5] Qing Arn Ng;Yeong Shiong Chiew;Xin Wang;Chee Pin Tan;Mohd Basri Mat Nor;Nor Salwa Damanhuri;J. Geoffrey Chase; (2021). Network Data Acquisition and Monitoring System for Intensive *Care Mechanical Ventilation Treatment. IEEE Access, doi:10.1109/access.2021.3092194*

[6] Md. Rakibul Islam;Mohiuddin Ahmad;Md. Shahin Hossain;Muhammad Muinul Islam;Sk. Farid Uddin Ahmed; (2020). Designing and Prototyping of an Electromechanical Ventilator based on Double CAM operation Integrated with Telemedicine Application . *2020 IEEE Region 10 Symposium (TENSYMP), (), – . doi:10.1109/TENSYMP50017.2020.9230673*

[7] Govoni, L; Farre, R; Pedotti, A; Montserrat, J M; Dellaca, R L (2010). [IEEE 2010 5th Cairo International Biomedical Engineering Conference (CIBEC 2010) - Cairo (2010.12.16-2010.12.18)] 2010 5th Cairo International Biomedical Engineering Conference - *An improved telemedicine system for remote titration and optimization of Home Mechanical Ventilation. , (), 66–69. doi:10.1109/cibec.2010.5716060*

*[8]*Calilung, E., Espanola, J., Dadios, E., Culaba, A., Sybingco, E., Bandala, A., … Castillo, C. J. P. (2020). Design and Development of an Automated Compression Mechanism for a Bag-Valve-Mask-Based Emergency Ventilator. 2020 IEEE 12th International Conference on Humanoid, Nanotechnology, *Information Technology, Communication and Control, Environment, and Management (HNICEM). doi:10.1109/hnicem51456.2020.9400150*

*[9]*Zhang, Y., Zhao, L., Yang, K., & Xu, L. (2020). Mobile Edge Computing for Intelligent Mining Safety: A Case Study of Ventilator. 2020 IEEE Intl Conf on Parallel & Distributed Processing with Applications, Big Data & Cloud Computing, Sustainable Computing & Communications, Social Computing & Networking(ISPA/BDCloud/SocialCom/SustainCom*).https://doi.org/10.1109/ispa-bdcloud-socialcom-sustaincom51426.2020.00192 doi:10.1109/ISPA-BDCloud-SocialCom-SustainCom51426.2020.00192*

[10] Lazzaro, N., Giannella, A., & Panerai, R. B. (1992). Clinical engineering and the quality of health care: The feasibility of low cost interventions. *Proceedings of the Annual International Conference of the IEEE Engineering in Medicine and Biology Society. doi:10.1109/iembs.1992.5761394*

Appendices

```
#include <Servo.h>
#include <LiquidCrystal_I2C.h>
#include "constants.h"

const int8_t pot_map_radius[3] = { 5, 5, 5 };
const uint16_t nom_vals[3][3] = { { 500, 300, 25 }, { 5, 5, 5 }, { 12, 25, 50 } };
const uint8_t val_inc[3][3] = { { 10, 5, 1 }, { 1, 1, 1 }, { 1, 1, 2 } };



const uint16_t base_delays[3] = { 950, 550, 200 };

const char clear_value[] = "        ";
const char *setting_titles[3] = { "Volume: ", "Pressure: ", "Breath Rate: " };
const char *age_titles[3] = { "Adult", "Child", "Infant" };
const char *unit[3] = { " mL", "/10", " br/m" };

bool ventilating = false;
bool time_to_squeeze = true;
bool time_to_release = true;
long squeeze_time = -100;
long release_time = -100;
bool compression_state = 0;
bool halt = false;
bool warn_user = false;
```

```
bool can_read_age_button = true;
long age_button_time = -100;
bool can_read_start_button = true;
long start_button_time = -100;

int8_t pot_vals[3] = { 0, 0, 0 };
uint8_t age_state = 0;

long red_led_flash = 0;
bool red_led_flash_on = false;

double sensitivity[] = {
  0.185,
  0.100,
  0.066
};
double voltage;
double current_sum = 0;

Servo servo;
LiquidCrystal_I2C lcd(0x27, 20, 4);

int map_pot_val(uint16_t unmapped_pot_val, int8_t pot_index) {
  return map(unmapped_pot_val, 0, 1024, pot_map_radius[pot_index], -pot_map_radius[pot_index]);
```

```
}


int16_t map_servo_pos(int16_t pos) {
  return map(pos, 0, MAX_SERVO_POS, 180, 0);
}


void lcd_update(uint8_t pot_index) {
  lcd.setCursor(LCD_H_SPACING - 1, pot_index + POT_LCD_OFFSET);
  lcd.print(clear_value);
  lcd.setCursor(LCD_H_SPACING, pot_index + POT_LCD_OFFSET);
  int16_t val = nom_vals[pot_index][age_state] + val_inc[pot_index][age_state] *
pot_vals[pot_index];
  lcd.print(val);
  lcd.print(unit[pot_index]);
}


void lcd_update_age() {
  lcd.setCursor(LCD_H_SPACING - 1, 0);
  lcd.print(clear_value);
  lcd.setCursor(LCD_H_SPACING, 0);
  lcd.print(age_titles[age_state]);
  for (uint8_t i = 0; i < 3; ++i) {
    lcd_update(i);
  }
}
```

```
void lcd_startup() {
  lcd.clear();
  lcd.setCursor(8, 0);
  lcd.print("YOUR");
  lcd.setCursor(0, 2);
  lcd.print("Automatic Inhalation");
  lcd.setCursor(4, 3);
  lcd.print("VENTILATOR");
}

void lcd_init_titles() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Age Group:");
  lcd.setCursor(0, 1);
  lcd.print("Volume:");
  lcd.setCursor(0, 2);
  lcd.print("Pressure:");
  lcd.setCursor(0, 3);
  lcd.print("Breath Rate:");
}

void lcd_init() {
  lcd_init_titles();
  lcd_update_age();
}
```

```
void check_pot_vals() {
  for (uint8_t i = 0; i < 3; ++i) {
    if (map_pot_val(analogRead(i + POT_PIN_OFFSET), i) != pot_vals[i]) {
      pot_vals[i] = map_pot_val(analogRead(i + POT_PIN_OFFSET), i);
      lcd_update(i);
    }
  }
}

void check_age_setting() {
  if (!digitalRead(P_SETTING_BUTTON) && can_read_age_button) {
    age_button_time = millis();
    can_read_age_button = false;
    age_state = (age_state + 1) % 3;
    lcd_update_age();
  }
}

void check_start_stop() {
  if (!digitalRead(P_START_BUTTON) && can_read_start_button) {
    if (warn_user) {
      red_led(true);
      warn_user = false;
```

```
      lcd_init();
    } else {
      start_button_time = millis();
      can_read_start_button = false;
      ventilating = !ventilating;
      red_led(!ventilating);
      green_led(ventilating);
    }
  }
}

bool check_halt() {
  if (ventilating && warn_user) {
    return true;
  }
  bool was_ventilating = ventilating;
  check_start_stop();
  if (was_ventilating && !ventilating) {
    return true;
  }
  return false;
}

uint8_t get_servo_delay() {
  uint16_t des_delay = nom_vals[PRES][age_state];
  des_delay += val_inc[PRES][age_state] * pot_vals[PRES];
```

```
  des_delay = map(des_delay, nom_vals[PRES][age_state] - pot_map_radius[PRES] * val_inc[PRES][age_state], nom_vals[PRES][age_state] + pot_map_radius[PRES] * val_inc[PRES][age_state], MIN_SPEED, MAX_SPEED);
  return des_delay;
}


void drive_servo(uint16_t desired_pos) {
  uint16_t servo_pos = servo.read();
  if (servo_pos < desired_pos) {
    for (int16_t pos = servo_pos; pos < desired_pos; pos += 1) {
      halt = check_halt();
      if (halt) {
        break;
      }
      servo.write(pos);
      delay(6);
    }
  }


  else {
    for (int16_t pos = servo_pos; pos > desired_pos; pos -= 1) {
      halt = check_halt();
      if (halt) {
        break;
      }
      servo.write(pos);
```

```
      update_current();
      uint8_t del = get_servo_delay();
      delay(del);
    }
  }
}

uint16_t get_ms_per_breath() {
  uint8_t breath_per_min = nom_vals[RATE][age_state] + val_inc[RATE][age_state] *
pot_vals[RATE];
  return round(1000 / (breath_per_min / 60.0));
}

uint16_t vol_to_ang(uint16_t vol) {
  return 4.89427e-7 * pow(vol, 3) - 8.40105e-4 * pow(vol, 2) + 0.64294 * vol +
28.072327;
}

void red_led(bool on) {

  analogWrite(P_RED_LED, on ? 5 : 0);
}

void green_led(bool on) {
  digitalWrite(P_GREEN_LED, on ? HIGH : LOW);
}
```

```
void flash_red() {
  if ((millis() - red_led_flash) > 200) {
    red_led(!red_led_flash_on);
    red_led_flash_on = !red_led_flash_on;
    red_led_flash = millis();
  }
}

double predict_current() {

  uint16_t v = nom_vals[0][age_state] + val_inc[0][age_state] * pot_vals[0];
  uint8_t p = nom_vals[1][age_state] + val_inc[1][age_state] * pot_vals[1];
  return -1.041041e3 + 2.35386 * v + 2.316309e-3 * pow(v, 2) - 3.887507e1 * p + 7.7198644 * pow(p, 2) - 4.2099326e-2 * v * p;
}

void update_current() {

  uint16_t potentiometer_raw = analogRead(P_CURRENT);
  double voltage_raw = (5.0 / 1023.0) * analogRead(VIN);
  voltage = voltage_raw - QOV + 0.012;
  double current = voltage / sensitivity[MODEL] * -1;
  current_sum += current;
}
```

```
void setup() {

  Serial.begin(9600);
  pinMode(P_RED_LED, OUTPUT);
  pinMode(P_GREEN_LED, OUTPUT);
  pinMode(P_SETTING_BUTTON, INPUT_PULLUP);
  pinMode(P_START_BUTTON, INPUT_PULLUP);
  servo.attach(P_SERVO);
  servo.write(map_servo_pos(START_POS));
  lcd.init();
  lcd.backlight();
  lcd_startup();
  red_led(true);
  green_led(true);
  delay(3000);
  lcd_init();
  green_led(false);
}

void loop() {
  if (!can_read_age_button && millis() - age_button_time >= 500) {
    can_read_age_button = true;
  }
  if (!can_read_start_button && millis() - start_button_time >= 500) {
    can_read_start_button = true;
  }
```

```
if (!warn_user) {
  if (!ventilating) {
    check_age_setting();
  }
  check_pot_vals();
}

if (halt) {
  compression_state = 0;
  ventilating = false;
  drive_servo(map_servo_pos(START_POS));
  release_time = millis();
}
halt = check_halt();

if (warn_user) {
  flash_red();
}

if (ventilating) {
  uint16_t ms_per_breath = get_ms_per_breath();
  int16_t post_breath_delay = ms_per_breath - base_delays[age_state];
  if (post_breath_delay < 0) {
    post_breath_delay = 1000;
  }
```

```
if (time_to_squeeze && !compression_state) {
  compression_state = 1;
  uint16_t des_vol = nom_vals[VOL][age_state];
  des_vol += val_inc[VOL][age_state] * pot_vals[VOL];
  uint16_t dest = vol_to_ang(des_vol);
  if (age_state == 0) {

    dest = map(dest, 193, 208, 180, 250);
  }
  drive_servo(map_servo_pos(dest));
  squeeze_time = millis();
} else if (time_to_release && compression_state) {

  if (current_sum >= predict_current() * 1.2 && age_state == 0) {
    halt = true;
    green_led(false);
    warn_user = true;

  } else {
    compression_state = 0;
    drive_servo(map_servo_pos(START_POS));
    release_time = millis();
  }
  current_sum = 0;
}
```

```
    if (compression_state) {
      update_current();
    }

    time_to_squeeze = millis() - release_time > post_breath_delay;
    time_to_release = millis() - squeeze_time > base_delays[age_state];
  }
}
```