VISVESVARAYA TECHNOLOGICAL UNIVERSITY

"Jnana Sangama", Belagavi-18,Karnataka,India

REVERSE ENGINEERING LABORATORY REPORT

on

"***VENTILATOR,DIALYSIS MACHINE AND MULTI-PARAMETER MONITOR***"

submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF ENGINEERING

in

MEDICAL ELECTRONICS ENGINEERING

During academic year 2022–2023

By

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Under the guidance of

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Accredited by National Board of Accreditation(NBA)

DAYANANDA SAGAR COLLEGE OF ENGINEERING

Shavige Malleshwara Hills, Kumaraswamy Layout,Bangalore-560078

An Autonomous Institute affiliated toVTU,Approved by AICTE and UGC,Accredited by NAAC with 'A' Grade & ISO 9001:2015 Certified Institution

DAYANANDA SAGAR COLLEGE OF ENGINEERING

DEPARTMENTOF MEDICAL ELECTRONICS

ENGINEERING

Vision and Mission of the Institute

VISION

To impart quality technical education with a focus on research and innovation, emphasizing on development of sustainable and inclusive technology for the benefit of society

MISSION

1. To provide an environment that enhances creativity and innovation in pursuit of excellence

2. To nurture team work in order to transform individuals as responsible leaders and entrepreneurs

3. To train the students to the changing technical scenario and make them to understand the importance of sustainable and inclusive technologies

Vision and Mission of the Department

VISION

To develop an excellent centre of progressive quality learning, applied & translational research through inventive collaborations and sustainable solutions to address healthcare related societal challenges

MISSION

1. By creating a conducive atmosphere for continuous learning through increased participation of students and faculty in various academic activities
2. By achieving needful and relevant healthcare solutions through quality education and research
3. By imparting education in the path of ethical and social responsibilities, to work effectively with diverse groups for the benefit of the society

DAYANANDA SAGAR COLLEGE OF ENGINEERING
DEPARTMENT OF MEDICAL ELECTRONICS
ENGINEERING

PROGRAM OUTCOMES(POs)

Engineering Graduates will be able to:

1. **Engineering Knowledge:** Apply the Knowledge of Mathematics, Science, Engineering Fundamentals, and an Engineering specialization to the solution of complex Engineering problems
2. **Problem Analysis:** Identify, Formulate, Review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of Mathematics, natural sciences and engineering sciences
3. **Design/Development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental conditions
4. **Conduct investigations on complex problems:** Use research based knowledge and research methods including design of Experiments, analysis and interpretation of data, and synthesis of Information to provide valid conclusions
5. **Modern tool usage:** Create, select, and apply appropriate technique, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations
6. **The Engineer and Society:** Apply reasoning informed by the contextual knowledge to assess society, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice
9. **Individual and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one’s work, as a member and leader in a team, to manage projects and in multidisciplinary environments
12. **Lifelong learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

DAYANANDA SAGAR COLLEGE OF ENGINEERING

DEPARTMENT OF MEDICAL ELECTRONICS ENGINEERING

Program Educational Objectives

Graduates will be able to:

PEO1: Apply knowledge of Medical Electronics to excel in their profession

PEO2:Practice Engineering to analyse problems and find solutions in allied domains using multi disciplinary approach

PEO3: Disseminate professional skills for ethical and societal responsibilities

PEO4: Engage in lifelong learning and contribute in the field of engineering research

Program Specific Outcomes

Graduates will be able to:

PSO1:Apply the knowledge of electronics for solving diverse problems of Medical Instrumentation

PSO2: Analyse and implement different techniques in Medical Image and Signal Processing domains catering to Design, Research and Development

PSO3: Provide sustainable solutions in health care and its allied fields by imbibing managerial and techno-social values

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Dialysis

What Is Dialysis :

Dialyzer reuse is the practice of you, the patient, using the same dialyzer for multiple treatments. Dialyzers are not just reused, they are reprocessed. The reprocessing procedure involves cleaning, testing, filling your dialyzer with a sterilant (Renalin® Cold Sterilant), inspecting, labeling, storing and rinsing your dialyzer before it is reused for your next treatment. Your dialyzer will be reprocessed carefully after each use by trained personnel. Detailed records of the dialyzer history will be kept. This will ensure that the dialyzer is safe for you to use again.

Urea pharmacokinetic equation systems have contributed to better understanding of treatment dose among hemodialysis patients. The methods are indirect, however, and require the measurement of blood urea nitrogen (BUN) concentration before and after a dialysis session to estimate the total treatment dose that clinicians prescribe [urea clearance × dialysis time (Kt)] indexed to an estimate of body size [the volume of urea distribution in the body (V)] yielding the ratio, Kt/V. New technology permits direct on-line measurement of average small molecule clearance (Kecn) during each dialysis treatment that can be multiplied by time (t) to give a direct measurement of total treatment dose (Kt). This study evaluated the relationship of measured Kt with death risk. It also evaluated the relationship of simple body size measures to risk and also the combination of one such measure [body surface area (BSA)] with Kt to death risk

Types:

There are two types of dialysis , each designed to meet differentneeds and cater to various medical situations. The types of dialysis include:

1. **Hemodialysis (HD)**

    In hemodialysis, a dialyzer (filtering machine) is used to remove waste andextra fluid from your blood, and then return the filtered blood into your body. Before starting hemodialysis, a minor surgery is needed to create a vascular access site (opening into one of your blood vessels), usually in your arm. This access site is important to have an easy way to get blood from your body, through the dialyzer, and back into your body. Hemodialysis can be done at a dialysis center or at home. Treatments usually last about four hours and are done three times per week. Some people may need more time for treatments based on their specific needs.

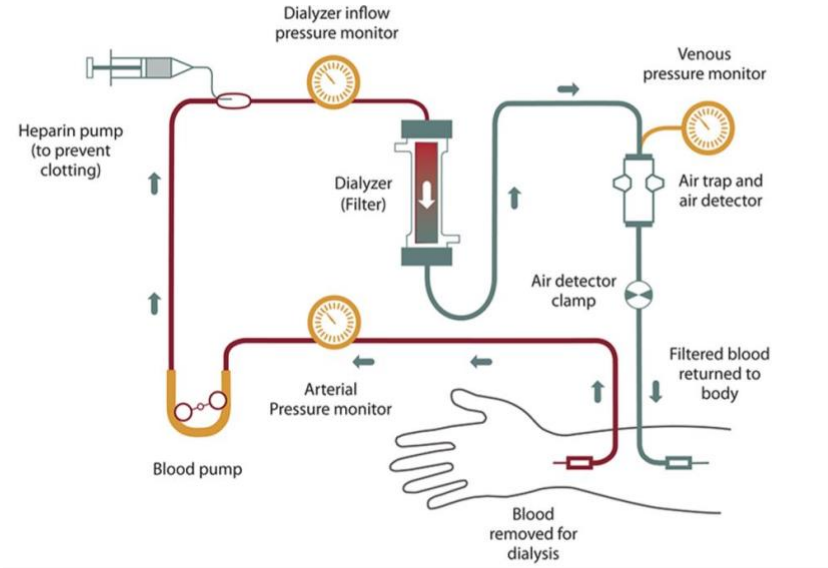


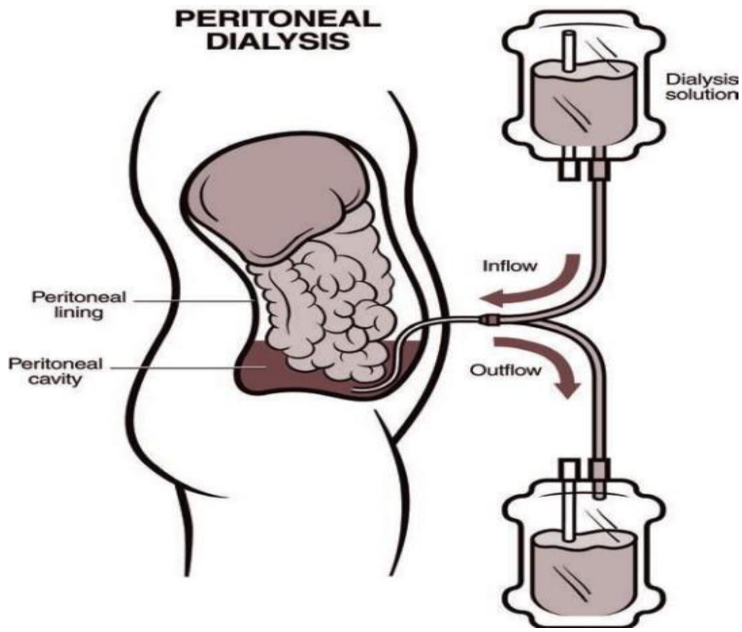
Fig 1.Working of dialysis machine

2. Peritoneal Dialysis (PD)

- In peritoneal dialysis, your blood is filtered inside your own body instead of using a dialyzer machine. For this type of dialysis, the lining of your abdomen or belly area (also called the peritoneum) is used as a filter. Before starting peritoneal dialysis, a minor surgery is needed to place a catheter (soft tube) in your belly. During each treatment, your belly area is slowly filled with dialysate (a cleansing fluid made from a mixture of water, salt, and other additives) through the catheter. As your blood flows naturally through the area, extra fluid and waste products are pulled out of the blood vessels andinto the belly area by the dialysate (almost like a magnet). After a few hours, the fluid mixture is drained from your belly using the same catheter and bag that was used at thebeginning of the treatment. Peritoneal dialysis can be done almost anywhere if you havethe supplies required to perform the treatment.

- Two of the most common types of peritoneal dialysis are:Continuous Ambulatory Peritoneal Dialysis (CAPD)
  Automated Peritoneal Dialysis (APD)

- The supplies and equipment needed, duration of each treatment (also known as an exchange), and number of treatments per day will differ depending on the type of PD you are using and your medical condition. More information about these treatments canbe found on the NKF Peritoneal Dialysis AtoZ page.



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- Fig 2.Dialysis

- **Functions:**

Dialysis serves as a life-saving medical procedure for individuals with kidney failure. Its key functions include removing waste products, excess fluids, and electrolytes from the blood, as well as helping maintain a proper balance of these substances in the body. Additionally, dialysis assists in controlling blood pressure and supporting overall metabolic functions, compensating for impaired kidney function.

A machine removes blood from your body, filters it through a dialyzer (artificial kidney) and returns the cleaned blood to your body. This 3- to 5-hour process may take place in a hospital or a dialysis center three times a week. You can alsodo hemodialysis at home.

Advantages:

- One of the main advantages of PD over hemodialysis is that the procedure can be carried out in the comfort of the patients' home. For most, all that is required is a washroom with fresh running water, a sterile area of the house for the procedure to take place, and space to store the fluid for dialysis. This also allows patients to travel.

- Kidney transplantation has a lot of benefits. The majority of patients will return toa virtually normal life within the first 1 to 2 weeks after surgery. With the exceptionof the medications they must take in the mornings and evenings, their social and professional lives will remain normal. They will no longer be depending on a machine for 3-4 hours each session, three times each week, as they are with dialysis.

- it is 'cleaned blood' no overall change in blood glucose levels.

Disadvantages:

- One of the most significant disadvantages of PD is that it’s required to be carriedout every day, which may act as an inconvenience for some. Furthermore, by undergoing PD specifically, there may be a greater risk of developing peritonitis –an infection of the abdomen.

- In some, quite rare instances, patients may experience scarring and thickening ofthe peritoneum. In order to prevent this, patients may have to change their treatment to hemodialysis.

- Additionally, those who undergo PD may report increased fatigue and malnutrition caused by the dialysis fluid, which can lower protein levels.

Specifications:

1. The structure of the machine should be of modular design.

It should have a Control & Monitoring Screen with minimum 10” coloured TFT/LCD Display (Screen). Display should have screen with high clarity & easily readable.

3. It should have Acetate & Bicarbonate dialysis facility.

4. It should have Sequential Ultra filtration facility. It should have Arterial Venous & Transmembrane pressure monitoring facility.

5. Blood pump flow rate should be from 30 ml/min to 600 ml/min.

6. It should have Single Needle dialysis facility.

7. It should have Volumetric Ultrafiltration System.

8. In-line Bicarbonate mixing and solution preparation facility during dialysis.

9. It should have Air bubble detector with Optical Sensor (to check the presence of blood in extracorporeal blood circuit) at Venous clamp.

10. It should have Heparin Infusion Pump with rate 1 to 10ml/min and Bolus Infusion upto 5ml/min

11. The typical single circuit electrical service is a 15 amp, 115 volt circuit. Consequently,of the approximately 1725 watts of available power, approximately only 1380 watts are available for use by the dialysis machine..

Fig 3.dialysis machine at reverse engineerimg lab

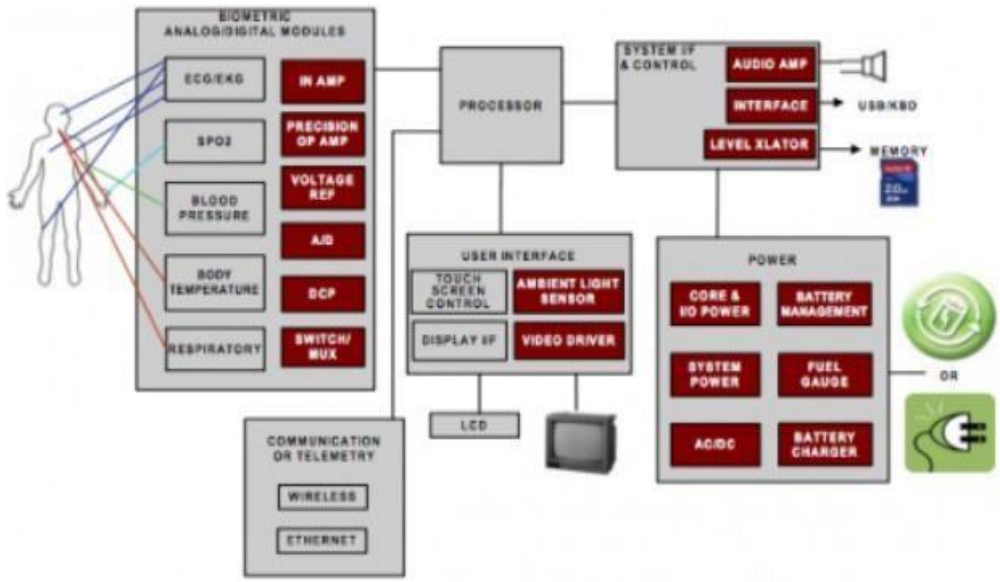
MULTIPARA MONITOR

A multipara monitor, often referred to as a multi-parameter monitor or patient monitor, is a medical device used for monitoring several physiological parameters of patients in healthcare settings. These monitors are commonly used in hospitals, clinics, and other healthcare facilities to provide continuous information about a patient's vital signs and other important parameters.

Multi-parameter patient monitors (MPMs) are widely used in intensive care units (ICUs) and general wards to continuously monitor patients' health based on the following human vital parameters: heart rate; blood pressure; respiration rate; and oxygen saturation (SPO2). MPMs in general require lower missing probability, probability for missing an alarm when an alarm is to be reported and false alarm probability, falsely reporting an alarm when there is no alarm to be reported. This means that the alarm accuracy, sensitivity and the no-alarm accuracy and specificity should be as high as possible.

Multi-parameter monitoring systems wear out over time and may no longer function correctly. Therefore, periodic planned maintenance of this type of system is relevant to increase thelongevity and availability, especially in critical environments as ICUs, increasing the reliability, and reducing the risk of failures.

Components of Multi-parameter monitor



Display Unit: The display unit is a screen that presents the monitored parameters in a clear and organized manner. It may be a high-resolution colour display that allows healthcare providers to easily view and interpret the data.

Parameter Modules: These are individual components or modules that monitor specific physiological parameters. Common parameters include:

- ECG (Electrocardiogram): Monitors the electrical activity of the heart.
- SpO2 (Pulse Oximetry): Measures the oxygen saturation of haemoglobin in the blood.
- NIBP (Non-Invasive Blood Pressure): Measures blood pressure without invasive procedures.
- Temperature: Monitors the patient's body temperature.
- Respiratory Rate: Measures the number of breaths per minute.

- CO_2 (Carbon Dioxide) Monitoring: Monitors the concentration of carbon dioxide in exhaled breath.
- Invasive Blood Pressure: Measures blood pressure using an invasive catheter.
- Cardiac Output: Measures the amount of blood pumped by the heart per minute.
- Depth of Anesthesia (BIS): Monitors the depth of anesthesia during surgery.

Central Processing Unit (CPU): The CPU processes the data from the parameter modules and controls the overall operation of the patient monitor.

Alarms: Alarms are crucial for alerting healthcare providers to abnormal values or changes in the patient's condition. Alarms can be audible, visual, or both.

Power Supply: Patient monitors are typically equipped with a power supply, and some may also have a battery backup to ensure continuous monitoring in case of power outages.

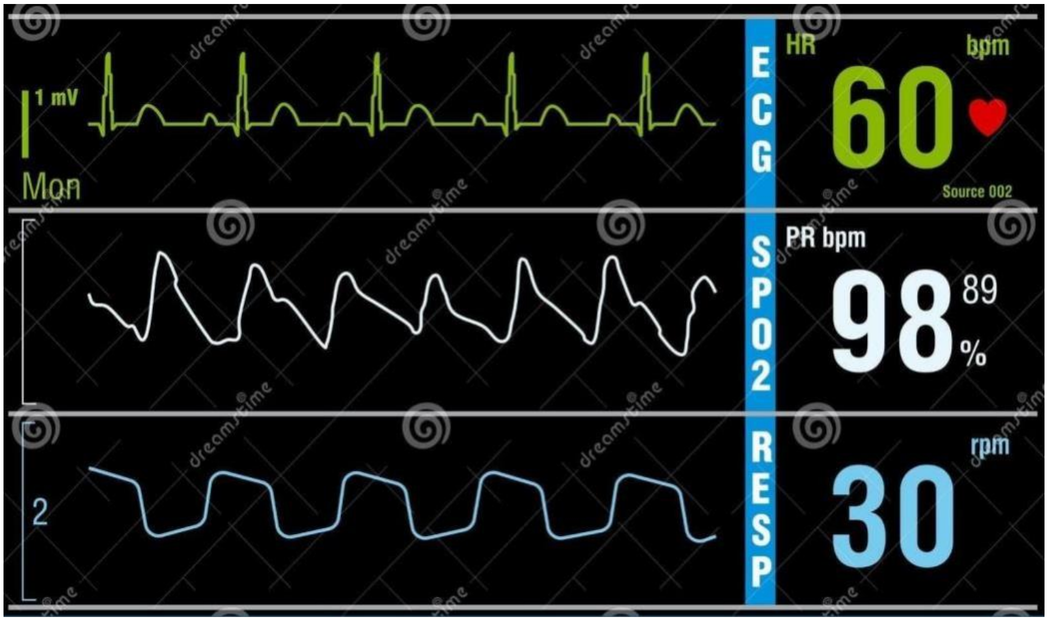
User Interface: This includes controls, buttons, and a touchscreen interface that allows healthcare providers to configure the monitor settings and access relevant information.

Networking and Connectivity: Some monitors have the capability to connect to hospital information systems, allowing for the integration of patient data into electronic health records.

Mounting and Mobility: Patient monitors may be mounted on rolling carts for mobility or integrated into the bed or wall-mounted for stationary use.

Trend and Data Storage: Some monitors have the capability to store and display trends of vital signs over time, which can be useful for retrospective analysis.

Working of Multi-parameter monitor



Parameter Measurement: The monitor consists of different parameter modules, each dedicated to monitoring a specific physiological parameter. These modules contain sensors or transducers that capture data from the patient. For example, an ECG module includes electrodes to measure the electrical activity of the heart, while a pulse oximetry module uses a sensor to measure blood oxygen saturation.

Signal Processing: The raw data collected by the sensors undergoes signal processing within the monitor's central processing unit (CPU). Signal processing includes filtering, amplification, and other techniques to enhance the accuracy and reliability of the measurements.

Data Integration: The processed data from various modules are integrated by the central processing unit to create a comprehensive overview of the patient's physiological status. This integrated data is then sent to the display unit for visualization.

Display and User Interface: The display unit presents the monitored parameters in real-time, typically on a high-resolution screen. The user interface allows healthcare providers to configure the monitor settings, set alarm thresholds, and access additional information. Touchscreens, buttons, and knobs are common components of the user interface.

Alarm System: The monitor is equipped with an alarm system that continuously compares the measured values against preset thresholds. If any parameter falls outside the normal range or if there is a significant change in the patient's condition, the alarm is triggered. This alerts healthcare providers to potential issues, allowing for timely intervention.

Power Supply and Backup: Patient monitors are usually connected to a power source, but they may also have a battery backup to ensure continued monitoring during power outages or when the device needs to be transported.

Networking and Connectivity: Some patient monitors have networking capabilities, allowing them to connect to hospital information systems or other devices. This facilitates the transfer of patient data and integration with electronic health records.

Data Storage and Trends: Many multi-parameter patient monitors can store historical data and trends over time. This information can be valuable for healthcare providers to review the patient's progress and make informed decisions about their care.

Calibration and Maintenance: Periodic calibration and maintenance are essential to ensure the accuracy of the measurements. This may involve regular checks and adjustments to the sensors and monitoring components.

VENTILATOR

A ventilator is a medical device that assists people in breathing when they're unable to do so adequately on their own. It supports the exchange of oxygen and carbon dioxide in the lungs by delivering breaths to the patient.

There are various types of ventilators, ranging from simple devices used for short-term support to sophisticated machines utilized in intensive care units (ICUs) for patients with severe respiratory problems. Ventilators work by supplying a controlled flow of oxygen-rich air into thelungs and removing carbon dioxide from the body.

These machines can be crucial in treating conditions such as pneumonia, acute respiratory distress syndrome (ARDS), chronic obstructive pulmonary disease (COPD), and other respiratory failures. Highly trained medical professionals, such as respiratory therapists and critical care doctors, oversee the use of ventilators to ensure they're appropriately set and used effectively for the patient's benefit.

Components of Ventilator

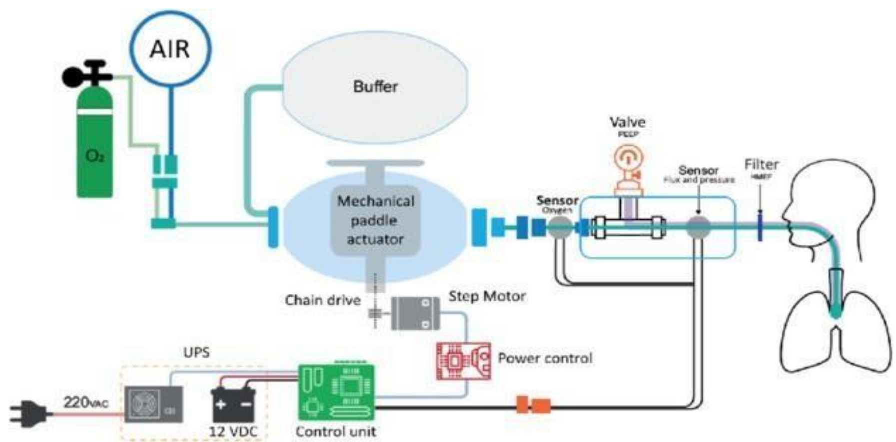


Fig. 7: Block diagram of ventilator

- **Control Panel and User Interface:** This is the interface through which healthcare professionals set and adjust various parameters, including the mode of ventilation, breath rate, tidal volume (the amount of air delivered in each breath), inspiratory and expiratory pressures, oxygen concentration, and alarms.
- **Breathing Circuit:** The breathing circuit connects the ventilator to the patient andincludes tubing, connectors, and the interface that delivers air to the patient's airway. It may consist of an endotracheal tube (for invasive ventilation), a mask, or nasal prongs(for non-invasive ventilation).
- **Gas Sources and Blending System:** Ventilators require a supply of medical gases, typically oxygen and air, which are blended to achieve the desired oxygen concentration for delivery to the patient.

- **Sensors and Monitors:** These sensors continuously monitor and display vital parameters such as oxygen saturation levels, carbon dioxide levels, airway pressure, respiratory rate, and sometimes hemodynamic parameters. Monitors provide real-time feedback to healthcare providers regarding the patient's respiratory status.
- **Power Source:** Ventilators are powered either by electricity or battery. They ofteninclude backup power systems to ensure continuous operation in case of power outagesor during patient transportation.
- **Alarms and Safety Features:** Ventilators are equipped with alarms to alert healthcare providers in case of issues such as low oxygen levels, high or low pressure, disconnection from the patient, or malfunction of the equipment. Safety features are in place to prevent over inflation of the lungs and to ensure patient safety.
- **Microprocessors and Software:** These components control the operation of the ventilator, managing the delivery of breaths according to the set parameters. They can also record and store data regarding the patient's respiratory status and the ventilator's performance.
- **Exhalation Valve and Filters:** The exhalation valve releases exhaled air and carbon dioxide from the patient. Filters within the system help maintain air quality and prevent contamination.

Functions of ventilator

- **Delivering Oxygen:** Ventilators deliver controlled amounts of oxygen to patients who have insufficient oxygen levels in their blood. This helps maintain proper oxygenation throughout the body.
- **Removing Carbon Dioxide:** Ventilators aid in eliminating carbon dioxide (CO2) from the body by assisting with the exhalation process. Proper removal of CO2 helps regulate the body's acid-base balance and prevents respiratory acidosis.
- **Generating Airway Pressure:** Ventilators create positive airway pressure to keep the airways open during inhalation, preventing collapse and allowing for better oxygen exchange in the lungs.

- **Providing Tidal Volume:** Tidal volume refers to the amount of air exchanged during each breath. Ventilators deliver a specified tidal volume, ensuring adequate air enters the lungs with each breath.
- **Controlling Breathing Rate:** Ventilators regulate the number of breaths delivered per minute based on the patient's needs. This function can be adjusted to achieve the desired respiratory rate.
- **Offering Different Ventilation Modes:** Ventilators provide various modes (e.g., volume-controlled, pressure-controlled, assist-control) to match the patient's condition and requirements. These modes determine how breaths are delivered and can be tailored to suit individual needs.
- **Adjusting Inspiratory and Expiratory Phases:** These machines control the timing and duration of both the inhalation (inspiratory phase) and exhalation (expiratory phase) of each breath, ensuring proper ventilation and gas exchange.

Ventilation modes

Ventilators offer various ventilation modes that determine how breaths are delivered and controlled. Each mode serves specific purposes and is tailored to accommodate different patient conditions. Some common types of ventilation modes include:

- **Volume-Controlled Ventilation (VCV):** In VCV, the ventilator delivers a preset tidal volume (amount of air per breath) to the patient with each breath. The machine maintains the volume regardless of changes in airway resistance or compliance, ensuring a consistent volume is delivered.
- **Pressure-Controlled Ventilation (PCV):** PCV delivers breaths at a set airway pressure. The ventilator maintains the desired pressure for a specified duration, allowing for more consistent pressures during inspiration. The resulting tidal volume can vary depending on the patient's lung characteristics.
- **Assist-Control Ventilation (ACV):** ACV allows the patient to trigger the ventilator to deliver breaths either at a preset volume or pressure. If the patient's effort is detected, the ventilator provides full support by delivering a preset volume or pressure-controlled breath.

- **Synchronized Intermittent Mandatory Ventilation (SIMV):** SIMV combines controlled breaths (either volume or pressure-controlled) with spontaneous breaths initiated by the patient. The machine delivers a set number of breaths per minute, but the patient can also take additional breaths between the ventilator-delivered breaths.
- **Pressure Support Ventilation (PSV):** PSV assists spontaneous breathing efforts by delivering a preset level of pressure support during inhalation. It augments the patient's own efforts, making breathing easier by reducing the work of breathing against airway resistance.
- **Continuous Positive Airway Pressure (CPAP) and Bi-Level Positive Airway Pressure (BiPAP):** These modes are used in non-invasive ventilation. CPAP provides a continuous positive pressure throughout the breathing cycle, while BiPAP delivers two levels of pressure, higher during inhalation and lower during exhalation, supportingpatients with conditions like sleep apnea or respiratory distress.
- **Proportional Assist Ventilation (PAV):** PAV adjusts the level of assistance provided by the ventilator based on the patient's respiratory efforts. It assists in proportion to the patient's inspiratory efforts, offering a more individualized approach to ventilation.
- **Inverse Ratio Ventilation (IRV):** IRV involves a prolonged inspiratory phase compared to the expiratory phase, which can be beneficial in improving oxygenation in specific conditions, such as acute respiratory distress syndrome (ARDS).

Types of ventilators

There are several types of ventilators, each designed to meet different needs and cater to various medical situations. The types of ventilators include:

- **Invasive Ventilators:** These ventilators require inserting a tube into the patient's airway through the mouth (oral intubation) or nose (nasal intubation). Invasive ventilators are commonly used in critical care situations, surgeries, or for patients who cannot breathe adequately on their own. They provide full respiratory support and are highly customizable with various modes and settings.
- **Non-Invasive Ventilators**: These ventilators deliver breathing support without the need for an artificial airway tube. They include devices like continuous positive airway pressure (CPAP) and bilevel positive airway pressure (BiPAP) machines. They're often

used for conditions like sleep apnea, certain respiratory issues, or as an initial treatment before resorting to invasive methods.

- **Portable Ventilators**: These are lightweight and mobile ventilators designed for transportation or for use outside the hospital setting. They are battery-powered and offer varying levels of respiratory support, making them suitable for use during patient transfers or in emergency medical services.
- **Volume-Controlled Ventilators:** These machines deliver a set volume of air with each breath at a predetermined rate. They are commonly used in critical care settings and are helpful in ensuring a consistent volume of air is delivered to the patient's lungs.
- **Pressure-Controlled Ventilators:** These ventilators maintain a set pressure in the patient’s airways during inhalation. They are often used in cases where minimizing pressure on the lungs is necessary such as in patients with acute lungs injury or ARDS.
- **Dual-Purpose Ventilators:** Some ventilators are designed for both invasive and non-invasive use. These machines offer flexibility, allowing healthcare providers to switch between invasive intubation and non-invasive masked based ventilation as needed.
- **High-Frequency Oscillatory Ventilators (HFOV):** HFOV delivers very rapid breaths at small tidal volumes. It’s used in some cases of severe respiratory distress where conventional ventilation methods might not be as affective.
- **Neonatal/Pediatric Ventilators:** These ventilators are specifically designed for newborns and infants. They are equipped with specialized features to cater to the unique needs of pediatric patients, providing precise control over the breaths delivered and accounting for their smaller lung capacities.