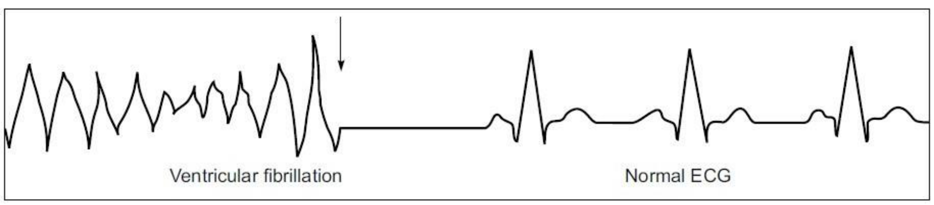
CARDIAC DEFIBRILLATORS

NEED FOR A DEFIBRILLATOR

- Ventricular fibrillation is a serious cardiac emergency resulting from asynchronouscontraction of the heart muscles. This uncoordinated movement of the ventricle wallsof the heart mayresult from coronary occlusion, from electric shock or fromabnormalities of body chemistry.
- Because of this irregular contraction of the muscle fibres, the ventricles simply quiverrather than pumping the blood effectively. This results in a steep fall of cardiac outputand can prove fatal if adequate steps are not taken promptly.
- In fibrillation, the main problem is that the heart muscle fibres are continuouslystimulated by adjacent cells so that there is no synchronised succession of events thatfollow the heart action. Consequently, control over the normal sequence of cell actioncannot be captured by ordinary stimuli.

DEFIBRILLATOR

- Ventricular fibrillation can be converted into a more efficient rhythm by applying a high energy shock to the heart. This sudden surge across the heart causes all muscle fibres to contract simultaneously. Possibly, the fibres may then respond to normal physiological pacemaking pulses. The instrument for administering the shock is called a defibrillator.



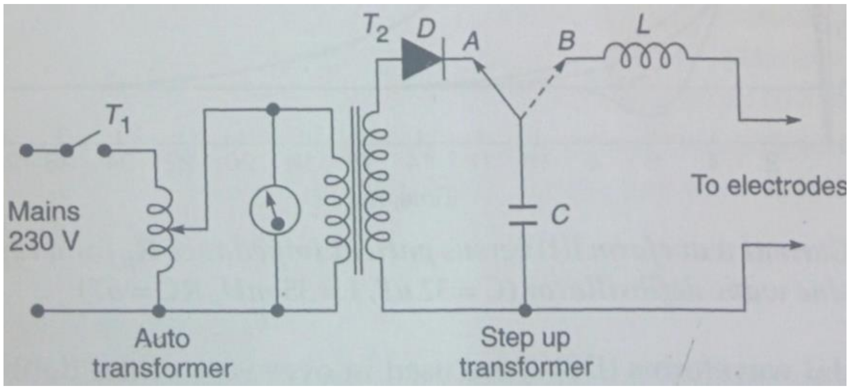
Restoration of normal rhythm in fibrillating heart as achieved by direct current shock

The shock can be delivered to the heart by means of electrodes placed on the chest of thepatient (external defibrillation) or the electrodes may be held directly against the heart whenthe chest is open (internal defibrillation). Higher voltages are required for externaldefibrillation than for internal defibrillation.

DC DEFIBRILLATOR

Basic Principle

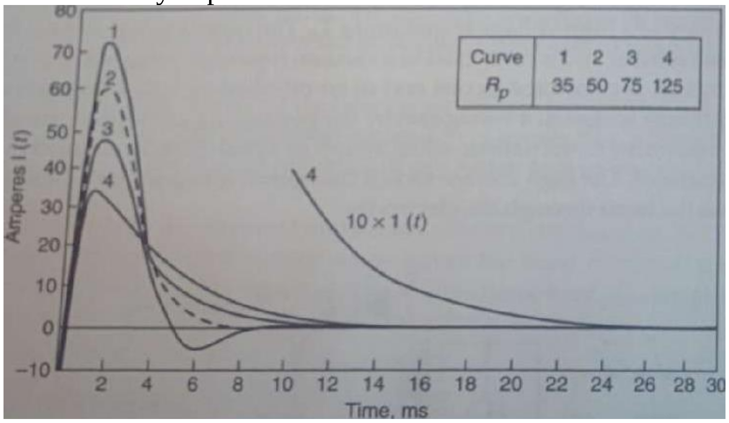
In this an energy storage capacitor is charged at a relatively slow rate (in the order ofseconds) from the AC line by means of a step-up transformer and rectifier arrangement orfrom a battery and a DC to DC converter arrangement. During defibrillation, the energystored in the capacitor is then delivered at a relatively rapid rate (in the order of milliseconds)to the chest of the subject. For effective defibrillation,it is advantageous to adopt some shaping of the discharge current pulse. The simplest arrangement involves the discharge of capacitor energy through the patient's own resistance (R). This yields an exponential discharge typical of an RC circuit. If the discharge is truncated, so that the ratio of the duration of the shock to the time constant of decay of the exponential waveform is small, the pulse of current delivered to the chest has a nearly rectangular shape. For a somewhat larger ratio, the pulse of current appears nearly trapezoidal. Rectangular and trapezoidal waveforms have also been found to be effective in the trans-thoracic defibrillation and such waveforms have been employed in defibrillators designed for clinical use.



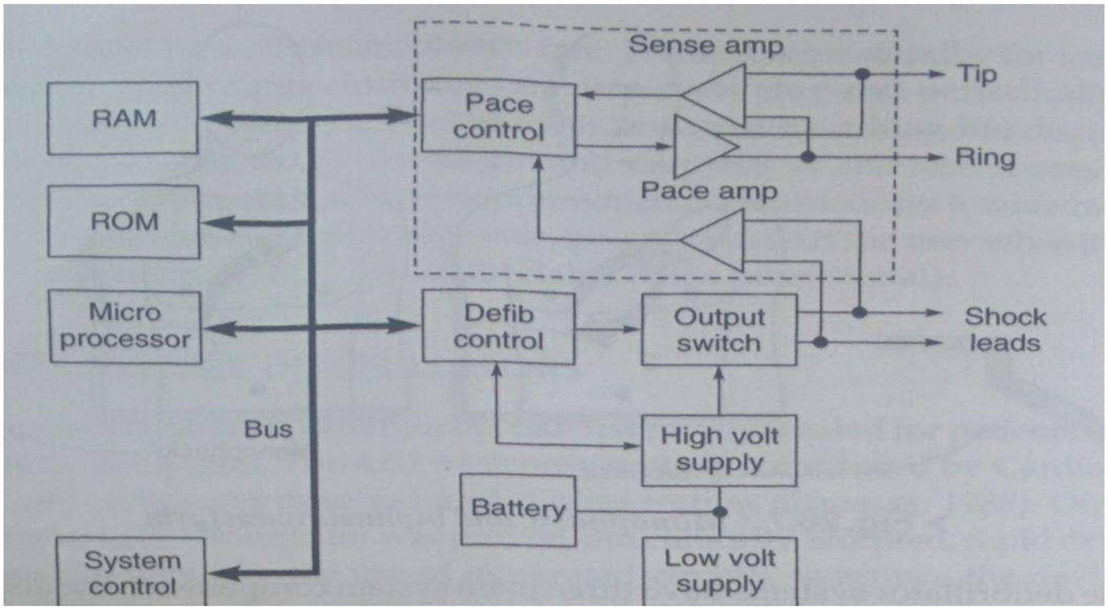
- A variable auto-transformer Tj forms the primary of a high voltage transformer T2. The output voltage of the transformer is rectified by a diode rectifier and is connected to a vacuum type high vol tage change-over switch. In position A, the switch is connected to one end of an oil- filled 16 micro-farad capacitor.
- In this position, the capacitor charges to a voltage set by the positioning of the autotransformer. When the shock is to be delivered to the patient, a foot switch or a push button mounted on the handle of the electrode is operated. The high voltage switch changes over to position 'B' and the capacitor is discharged across the heart through the electrodes.
- In a defibrillator, an enormous voltage (approx. 4000 V) is initially applied to the patient.

Discharging Pulse of a DC defibrillator

- The most common waveform utilized in the RLC circuit employs an under-dampedresponse with a damping lector lea than unity.
- This particular waveform is called a Lown' waveform. This waveform is more or leasof an oscillatory character, with both positive and negative portion. The pulse width inthis waveform is defined as the time that elapses between the start of the impulse andthe moment that the current intensity passes the zero line for the first time andchanges direction.
- The pulse duration is usually kept as 5 ms or 2.5 ms.



IMPLANTABLE DEFIBRILLATORS



- An implantable defibrillator is continuously monitors a patient's heart rhythm.
- If the device detects fibrillation, the capacitors within the device are charged up to 750 V. The capacitors then discharged into the heart which mostly represents a resistive load of 50 *ohm* and to bring heart into normal rhythm.
- This may require delivery of more than one high energy pulse.
- Implantable defibrillator systems have three main system components: the defibrillator itself (AID), the lead system, and the programmer recorder/monitor (PRM). The AID houses the power source, sensing, defibrillation, pacing, and telemetric communication system. The leads system provides physical and electrical connection between the defibrillator and the heart tissue. The PRM communicateswith the implanted AID and allows the physician to view status information andmodify the function of the device as needed.

Programmer Recorder/Monitor (PRM):

- The PRM is an external device that providesa bidirectional communications link to an implanted AID. This telemetry link isestablished from a coil which is contained within the wand of the PRM, to a coilwhich is contained within the implanted device. This telemetry channel may be usedto retrieve real-time and stored intracardiac ECG, therapy history, battery status, andother information pertaining to device function. A number of combinations ofprogrammable therapy and detection options are available and it is not unusual to alterthese prescriptions dozens of times over the life of the implant.

Leads:

- Until recently, the defibrillating high energy pulse was delivered to the heartvia a 6 cmx9 cm titanium mesh patch with electrodes placed directly on the externalsurface of the heart. Sensing wasprovided through leads screwed in the heart. Thisapproach required an invasive surgical approach to provide access to the heart. Themodem implantable defibrillators make use of a single transvenous lead with themultiple electrodes inserted into the right ventricle for ventricular pacing anddefibrillation.

Pulse Generator

- It has **a** microprocessor which controls overall system functions. An 8-bitdevice is sufficient for most systems**. ROM** provides non-volatile memory for systemstart-up tasks and some program space, whereas RAM is required for storage ofoperating parameters, and storage of electro-cardiogram data. The system control partincludes support circuitry for the microprocessor like a telemetry interface, typicallyimplemented with a UART-like (universal asynchronous receiver/transmitter)interface and general-purpose timers.

- The power supply to the circuit comes from lithium Silver Vanadium oxide (Li SVO)batteries. Digital circuits operate from 3 V or lower supplies whereas analog circuitstypically require precision nanoampere current source inputs. Separate voltagesupplies are generated for pacing (approximately 5 V) and control of the chargingcircuit (10-15 V),
- High power circuits convert the 3-6 V battery voltage to the 750 V necessary for adefibrillation pulse, store the energy in high voltage capacitors for timed delivery, andfinally switch the high voltage to cardiac tissue or discharge the high voltageinternally if the cardiac arrhythmia self-terminates. The major components of thesecircuits are the battery, the DC-to-DC converter, the output storage capacitors, and the high-power output switches.
- Commercially available implantable defibrillators all utilize lithium SVO cells, withthe most common configuration being two connected in series to form anapproximately 6 V battery. Unlike 2.8 V lithium iodide (LI) pacemaker cells whichdevelop high internal impedance asthey discharge (up to 20,000 Q over their usefullife), SVO cells are characterized by low internal impedance (less than 1ft) over theiruseful life. The output voltage of SVO is higherthan LI ranging from 3.2 V for afresh cell to approximately 2.5 V when nearly depleted.
- DC to DC converter used to convert the 6 volt battery voltage to 750 V is of classicalconfiguration. They are operated at as high a frequency (in the range of 30-60 KHz)as practical to facilitate the use of the smallest possible core.
- The storage capacitors are typically aluminium electrolytics because of the highvolumetric efficiency and working voltage required. Most designs utilize at least twosuch capacitors in series.

Ventilators

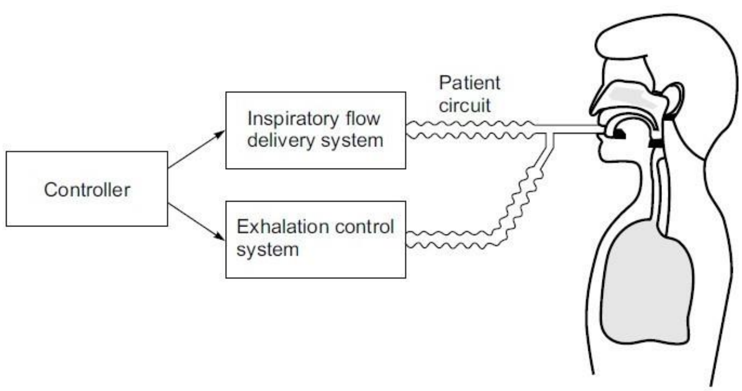
- An integral component of the anaesthetic delivery system is the ventilator. The ventilator provides a positive force for transporting respiratory and anaesthetic gases into an apneic patient. The ventilators provide positive pressure ventilation at a controlled minute volume (Tidal volume, Rate). They operate either electronically or mechanically with pneumatic or electric power source.
- Anaesthetic machine ventilators have a minimal number of controls. The anaesthetist could vary minute volume by setting tidal volume and ventilatory frequency directly or by adjusting inspiratory time, inspiratory flow rate and the ratio of inspiratory to expiratory time. The newest models resemble critical care ventilators in their capabilities.
- These may perform self-test upon start-up, volume or pressure-controlled ventilation modes, assisted spontaneous ventilation and electronically adjustable PEEP. Sophisticated spirometry compensates for changes in fresh gas flow, small leaks or patient compliance.
- Most of the currently used ventilators consist of a bellows contained within another housing.
- The bellows communicate directly with the breathing circuit and causes a pre-selected volume of gas to flow into the patient. The flow of gas into the circuit results from collapsing the

ventilator bellows by pressurizing the surrounding gas volume contained within the bellows housing.

- The ventilator is either located within the mainframe of the anaesthesia machine or is attached as an accessory unit. The outlet of the ventilator connects directly to the patient breathing circuit of the anaesthetic delivery system at the location and in place of the breathing reservoir bag. The ventilator thus functions as a controller for both ventilation and circuit gas supply by replacing the functions of the reservoir bag and APL valve.
- When artificial ventilation needs to be maintained for a long time, a ventilator is used. Ventilators are also used during anaesthesia and are designed to match human breathing waveform/pattern.
- These are sophisticated equipment with a large number of controls which assist in maintaining proper and regulated breathing activity. For short-term or emergency use, resuscitators areemployed. These depend upon mechanical cycle operation and are generally light-weight andportable.
- The main function of a ventilator is to ventilate the lungs in a manner as close to natural respiration as possible. Since natural inspiration is a result of negative pressure in the pleural cavity generated by the movement of the diaphragm, ventilators were initially designed to create the same effect. These ventilators are called negative-pressure ventilators. In this design, the flow of air to the lungs is facilitated by generating a negative-pressure around the patient'sthoracic cage. The negative-pressure moves the thoracic walls outward, expanding the intrathoracic
- Volume and dropping the pressure inside the lungs, resulting in a pressure gradient between the atmosphere and the lungs which causes the flow of atmospheric air into the lungs.
- The inspiratory and expiratory phases of the respiration are controlled by cycling the pressure inside the body chamber.

Positive-pressure ventilators generate the inspiratory flow by applying a positive pressure—greater than the atmospheric pressure—to the airways. During the inspiration, the inspiratory flow delivery system creates a positive pressure in the patient circuit and the exhalation control system closes the outlet to the atmosphere. During the expiratory phase, the inspiratory flow delivery system stops the positive pressure at the exhalation system and opens the valves to allow the exhaled air to the atmosphere.

Positive-pressure ventilators operate either in mandatory or spontaneous mode. In spontaneous breath



➤ Fig. 33.3 *Functional diagram of a positive pressure ventilator*

delivery, the ventilator responds to the patient's effort to breathe independently. Therefore, the patientcan control the volume and the rate of respiration. Spontaneous breath delivery is used for those patients who are on their way to full recovery but are not completely ready to breathe from the atmosphere without mechanical assistance. when delivering mandatory breaths, the ventilator controls all parameters of the breath such as tidal volume, inspiratory flow waveform, respiration rate and oxygen content of the breath. Mandatory breaths are normally delivered to the patients who are incapable of breathing on their own

TYPES OF VENTILATORS

Anaesthesia Ventilators: These are generally small and simple equipment used to give regular assisted breathing during an operation.

Intensive Care Ventilators: Intensive care ventilators are more complicated, give accurate control over a wider range of parameters and often incorporate ‘patient triggering facility.

VENTILATOR TERMS

Lung Compliance: The compliance of the patient’s lungs is the ratio of volume delivered to the pressure rise during the inspiratory phase in the lungs. This includes the compliance of the airways. Compliance is usually expressed as litres/cm H2O.

Lung compliance is the ability of the alveoli and lung tissue to expand on inspiration. The lungs are passive, but they should stretch easily to ensure the sufficient intake of the air. A ventilator and other parts of the breathing circuit also have compliance and some of the delivered volume is used to compress gas or expand gas in these parts.

The compliance of a patient’s lungs is the ratio of pressure drop across the airway to the resulting flow rate through it. It is also expressed as cm H2O/litres (pressure drop/flow rate).

Airway Resistance: Airway resistance relates to the ease with which air flows through the tubular respiratory structures. Higher resistances occur in smaller tubes such as the bronchioles and alveoli that have not emptied properly.

Mean Airway Pressure (MAP): An integral taken over one complete cycle expresses the mean airway pressure. Inspiratory Pause Time: When the pressure in the patient circuit and alveoli is equal, there is a period of no flow. This period is called inspiratory pause time.

Inspiratory Flow: Inspiratory flow is represented as a positive flow above the zero line.

Expiratory Flow: Expiratory flow is a negative flow below the zero line.

Tidal Volume: Tidal volume is the depth of breathing or the volume of gas inspired or expired during each respiratory cycle

Minute Volume: This refers to volume of gas exchanged per minute during quiet breathing.

Minute volume is obtained by multiplying the tidal volume by the breathing rate.

CLASSIFICATION OF VENTILATORS

- Based on the Method on Inspiratory Phase
- Based on Power Transmission
- Based on Pressure Pattern
- Based on the Type of Safety Limit
- Based on Cycling Control
- Cycling from Inspiration to Expiration
- Cycling from Expiration to Inspiration
- Based on the Source of Power

MODERN VENTILATORS

The current and future trends in critical care ventilatory management demand precise flow, pressure and oxygen control for application to both adult and paediatric patients. Modern ventilator machines consist of two separate but inter-connected systems:

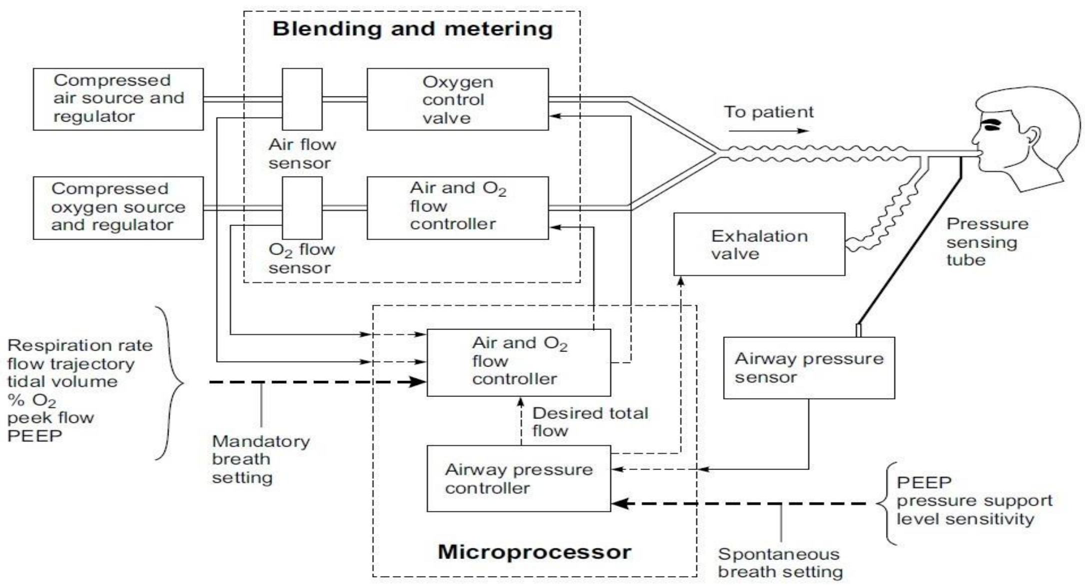
The pneumatic flow system

An electronic control system.

- The pneumatic flow system enables the flow of gas through the ventilator. Oxygen and medical grade air enter the ventilator at 3.5 bar (50 psi) pressure through built-in 0.1-micron filters. The normal operating range is 2 to 6 bar or 28 to 86 psi. These gasses enter the air/oxygen mixer where they combine at the required percentage and reduced in pressure to 350 cm H2O.

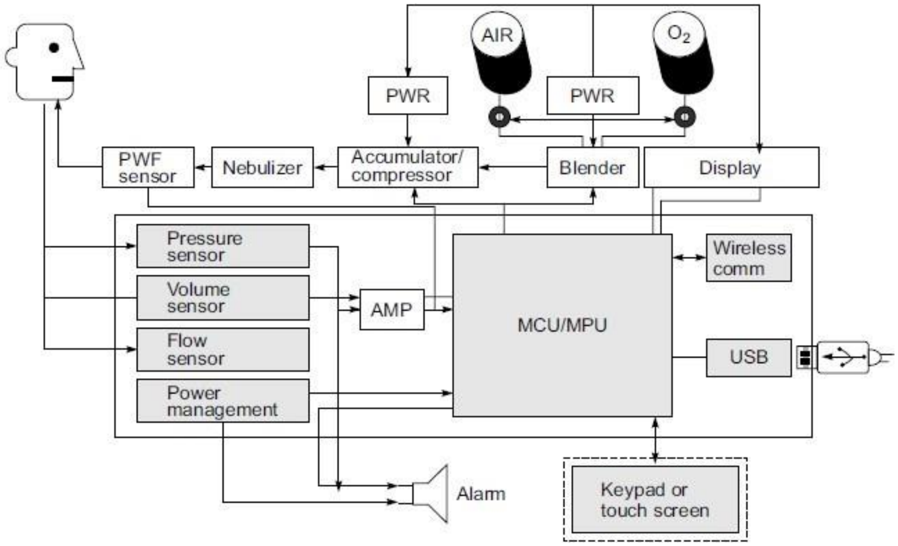
- The gasses then enter a large reservoir tank which holds about 8 litres of mixed gasses, when compressed to 350 cm H2O. An electronically controlled flow valve proportions the gas flow from the reservoir tank to the patient breathing circuit. In some ventilators, an air compressor is used in place of a compressed air tank. The primary objective of the device is to ensure proper

  level of oxygen in the inspiratory air and deliver a tidal volume according to the clinical requirements.
- As the gasses leave the ventilator, they pass by an oxygen analyser, a safety ambient air inlet valve and a back-up mechanical over pressure valve. The ambient valve provides the patient the ability to breathe room air when the ventilator fails or the pressure in the patient circuit drops below–10 cm of H2O. In the patient breathing circuit is a bi-directional flow sensor to measure the gas flows. The exhaled gasses exit through an electronically controlled exhalation valve located at the ventilator. The microprocessor controls each valve to deliver the desired inspiratory air and oxygen flows for mandatory and spontaneous ventilation.
- The electronic control system may use one or more microprocessors and software to performmonitoring and control functions in a ventilator. These parameters include setting of therespiration rate, flow waveform, tidal volume, and oxygen concentration of the delivered breath,peak flow and PEEP. The PEEP selected in the mandatory mode is only used for control ofexhalation flow. The microprocessor utilizes the above parameters to compute the desiredinspiratory flow trajectory. The system consists of monitors for pressure flow and oxygen
- Fraction. The sensors are connected to electronic processing circuits which makes them availablefor digital readouts. The signals are also compared with pre-set alarm levels so that if they falloutside a pre-determined normal range, alarms are sounded.
- The flow sensor usually consists of a variable orificeand by measuring the pressure drop across the variable orifice, the patient flows can be calculated.Ventilators are lifesaving equipmentand therefore need regular maintenance and calibration.



➤ Fig. 33.12 *Block diagram of a microprocessor controlled ventilator*

- The most common indices of the ventilation apparatus are the absolute volume and changes of volume of the gas space in the lungs achieved during a few breathing manoeuvres. The ventilator is constantly monitored and adjusted to maintain appropriate arterial pH and PaO2.
- This system requires a set of sensors for pressure, volume and flow. The information from the sensors modulates the operations in the microcontroller unit (MCU). This MCU receives information from the airways, lungs and chest wall through the sensors and decides how the ventilator pump responds.



- The signal that shows lung volume is a differential signal, but this is not the signal measured
- Directly from the lungs using transducer. The air and oxygen blender provides a precise oxygen concentration by mixing air and oxygen.
- Internally, a proportioning valve mixes the incoming air and oxygen as the oxygen percentage dial is adjusted. Variation in line pressure, flow or pressure requirements for any attached device will not affect the oxygen concentration. The MCU uses a PWM (Pulse Width Modulator) to control the blender electro valves through a motor control design.
- An important part of the circuit is an alarm system that can indicate different patient parameters such as exhaled volume or airway pressure.
- The ventilation system must be ableto detect whether a breath has been taken. The MCU measures changes in aspiratory flow andpressure by using sensors. If no inspiration is detected within a certain period of time, themonitor sounds an alarm. The conditions to be programmed depend on each system. PWMcycles can be programmed to sound the alarms.

Nerve Simulator

Electrical nerve stimulation is an option for individuals who have unsuccessfully tried other pain management options. It is especially useful for those who experience failed back surgery, complex regional pain syndrome, seizures or multiple sclerosis.
Nerve stimulators can be a useful option when chronic pain doesn't respond to physical therapy, medication or surgery.

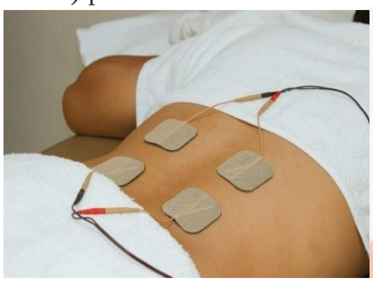
Types of Nerve Simulator

- Transcutaneous electrical nerve stimulation (TENS)
- peripheral nerve stimulation (PNS)

- spinal cord stimulation (SCS)

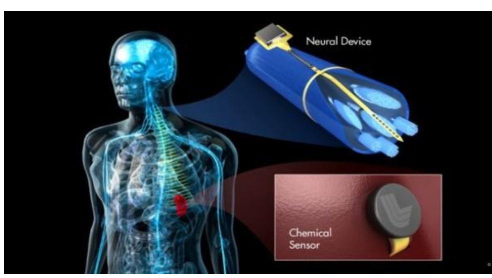
Transcutaneous electrical nerve simulation

- Transcutaneous electrical nerve stimulation (TENS) is a therapy that uses low voltage electrical current to provide pain relief. A TENS unit consists of a battery-powered device that delivers electrical impulses through electrodes placed on the surface of your skin. The electrodes are placed at or near nerves where the pain is located or at trigger points.
- There are two theories about how transcutaneous electrical nerve stimulation (TENS) works.
- One theory is that the electric current stimulates nerve cells that block the transmission of pain signals, modifying your perception of pain.
- The other theory is that nerve stimulation raises the level of endorphins, which are the body's natural pain-killing chemical. The endorphins then block the perception of pain.
- TENS therapy has been used or is being studied to relieve both chronic (long lasting) and acute (short-term) pain.




Peripheral nerve stimulation (PNS)

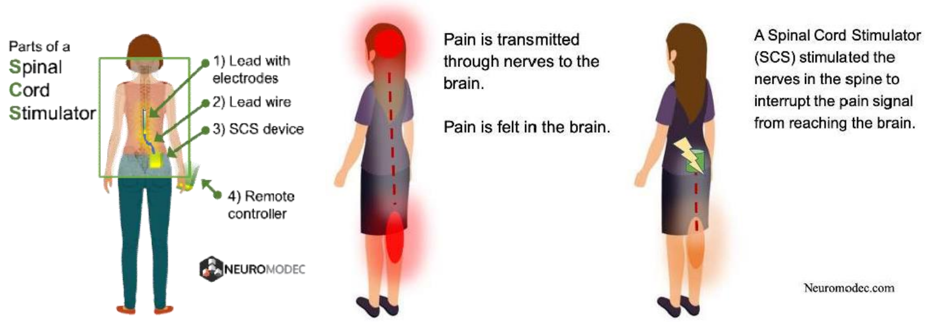
- Peripheral nerve stimulation, frequently referred to as PNS, is a commonly used approach to treat chronic pain.
- It involves surgery that places a small electrical device (a wire-like electrode) next to one of the peripheral nerves. (These are the nerves that are located beyond the brain or spinal cord). The electrode delivers rapid electrical pulses that are felt like mild tingles (so-called paresthesias).
- During the testing period (trial), the electrode is connected to an external device, and if the trial is successful, a small generator gets implanted into the patient's body. Similar to heart pacemakers, electricity is delivered from the generator to the nerve or nerves using one or several electrodes.
- The patient is able to control stimulation by turning the device on and off and adjusting stimulation parameters as needed



Spinal cord stimulation (SCS)

- A spinal cord stimulator (SCS) device is surgically placed under your skin and sends a mild electric current to your spinal cord.
- The spinal cord device consists of a pulse generator, a small wire that carries the current from a pulse generator to the nerve fibers of the spinal cord.
- When turned on, the SCS stimulates the nerves in the area where your pain is felt. Pain is reduced when the electrical pulses modify and mask the pain signal from reaching your brain.

- SCS therapy is designed to help treat chronic, ongoing pain.



Spinal cord stimulation is a therapy that masks pain signals before they reach the brain. A small device, similar to a pacemaker, is implanted in the body to deliver electrical pulses to the spinal cord.It helps people better manage their chronic pain symptoms and decrease the use of opioid medications.It may be an option if you suffer chronic back, leg or arm pain and have not found relief with other therapies.

electrical impulses in order strengthen weak muscles, reduce swelling, relievewounds. pain and help heal

Neuromuscular electrical stimulati n (NMES)uses high intensities that cause excitation of peripheral nerves to produce a muscle contraction.The impulses are generated by a device and delivered through electrodes (pads that adhere to the skin) over the middle of the muscles that require stimulating. The impulses from EMS mimic the action potential (stimulus required to make the muscle contract) coming from the central nervous system. This causes the muscles to contract.

There are several uses for EMS and NMES which include:

- **Pain relief.** EMS can be us d at low levels to reduce the amount of pain you experience. This can be done by modulating the amount of pain signals to the brain or releasing natural pain-killers called endorphins.
- **Muscle contraction.** EMS can be used at different intensities to stimulate a muscle or helpmaintain muscle tone.