

### 3.1.1 PACEMAKER:

Pacemaker is an electrical pulse generator for starting and/or maintaining the normal heart beat. The output of Pacemaker is applied either externally to the chest or internally to the heart muscle. In case of cardiac standstill the use of pacemaker is temporary just long enough to start a normal heart rate. In long term pacing pacemaker is surgically implanted in the body and its electrodes are in direct contact with heart. In cardiac diseases where the ventricular rate is too low it can be increased to normal rate by using pacemaker.



**Fig 3.1.1: Pacemaker pulses**

The negatively going pulses to avoid ionization of muscles. Pulse repetition rate is usually 70 pulses/min but many pacemakers are adjustable in the range of 50-150pulses/min. The circulation of each pulse is between 1to2ms.

#### **Methods of stimulation:**

There are two types of stimulation

- (i) Internal stimulation
- (ii) External stimulation

#### **Internal stimulation:**

It is employed for long term pacing because of permanent damage. Electrodes in the form of fine wires of Teflon coated stainless steel. The current range is 2-5mA. Bipolar and Unipolar electrode are used.

Bipolar electrode : There are stimulating electrode and contact electrode which serves as a return path for current to pacemaker.

Unipolar electrode: There is only stimulating electrode and the return path for current to pacemaker is made through body fluids.

**External stimulation :**

It is employed to restart the normal rate of heart in case of cardiac stand still. The paddle shaped electrode are applied on the surface of chest current in the range of 20-150mA

**Based on the placement of pacemaker there are two types:**

- i. External pacemaker
- ii. Implanted (Internal pacemaker)

**Table 3.1.1:** External pacemaker Vs Internal Pacemaker

External pacemaker	Implanted(Internal ) pacemaker
The pacemaker is placed outside the body. It may be in the form of wrist watch or in packet from one wire go in to heart through the vein.	The pacemaker is surgically implanted beneath the skin near the chest
The electrode are called endocardiac electrode and are applied to heart.	The electrode are called myocardiac electrode and are in contact with heart muscle.
It does not the open chest surgery	It requires an open chest minor surgery
The battery can be easily replaced any defect or adjustment in the circuit can be easily attended without getting any help from a medical doctor	The battery can be replaced only by minor surgery. Further any defect or adjustment in the circuit cannot be easily attended. Doctors help is necessary to rectify the defect in the circuit.
During placement swelling and pain do not arise	During placement swelling and pain arise
There is no safety for the pacemaker particularly in the case of children	There is a cent percent safety
Mostly there are used for temporary heart damages.	Mostly there are used for permanent heart damages

**Different modes of operation:**

Pacing modes can be either competitive or noncompetitive. Asynchronous pacing is called competitive because the fixed rate impulses may occur along with natural pacing impulses and competition with them in controlling the heart beat. Non competitive pacemakers are programmed either in demand or synchronized mode

Based on the modes of operation pacemaker can be divided in to five types.

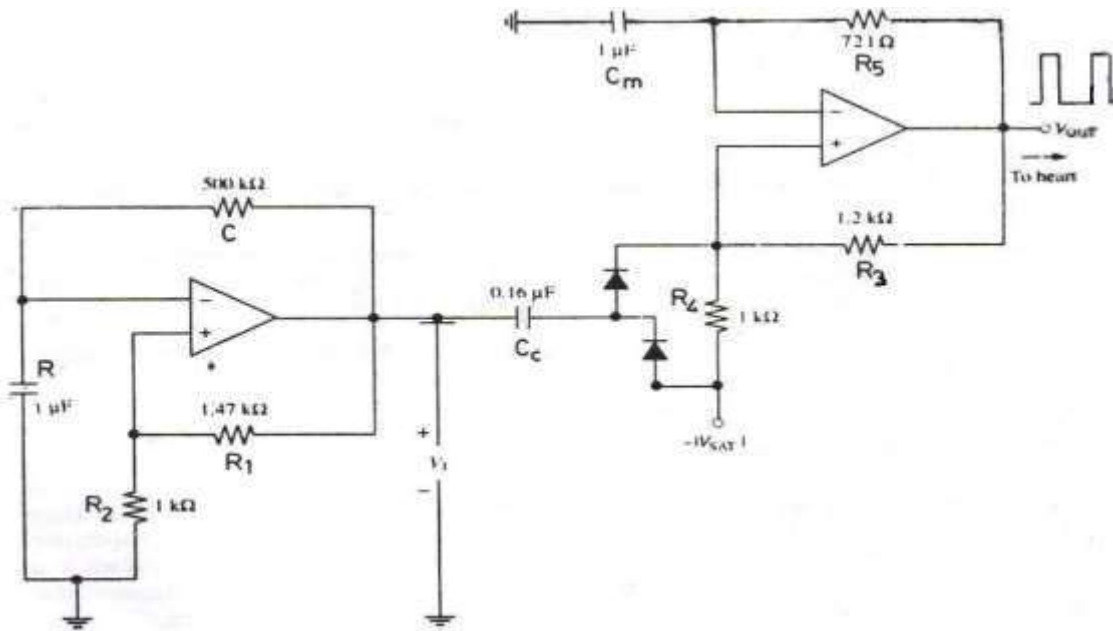
- i. Ventricular Asynchronous pacemaker (Fixed rate pacemaker)
- ii. Ventricular synchronous pacemaker
- iii. Ventricular inhibited pacemaker(Demand pacemaker)
- iv. Atrial synchronous pacemaker
- v. Atrial sequential Ventricular inhibited pacemaker

### **Ventricular Asynchronous pacemaker (Fixed rate pacemaker):**

It can be used in atrium or ventricle. It has the simplest mechanism and the longest battery life. This pacemaker is suitable for patients with either a stable, total AV block, a slow atrial rate. It is basically a simple astable multivibrator which produces at a fixed rate of heart.

There may be competition between the natural heart beats and pacemaker beats. If the pacemaker impulses reaches the heart during a certain period, ventricular fibrillation may occur. Nowadays the fixed pacemaker is fabricated on a large scale integrated circuit are used.

The circuit consists of a square wave generator and a positive edge triggered monostable multivibrator. The output of this combination provides a positively and negatively going square waves with equal duration for positive and negative pulses.



**Fig 3.1.2: Ventricular Asynchronous pacemaker**

The period of square wave generator is given by

$$\text{Where } \alpha = R_2 / (R_1 + R_2)$$

$\alpha$  – feedback voltage fraction

T can be changed by changing  $\alpha$  or time constant RC. The square wave generator is nothing but astable multivibrator which switches the output voltage between  $|V_{sat}|$  and  $-|V_{sat}|$ . The output of square wave generator is coupled to the positive edge triggered monostable multivibrator circuit. A positive edge trigger input will pass through capacitor  $C_c$  and diode and will raise the voltage at non-inverting terminal of second amplifier. The capacitor  $C_c$  is chosen so as to make five time constants equal to pulse duration TD. Otherwise the trigger would still be present after TD has passed and second pulse would be wrongly generated. Normally the pulse duration should not be affected by the loading of heart tissue.

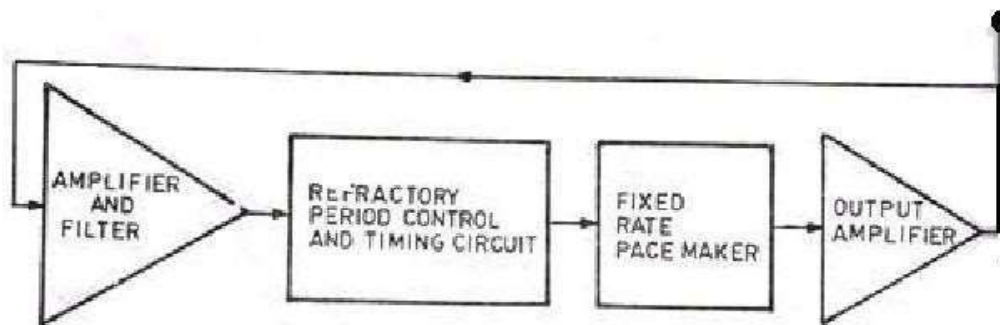
**Disadvantages:**

1. Using fixed rate pacemaker the heart rate cannot be increased
2. Simulation with a fixed impulse frequency results in the ventricles and atria beating at different rates. This varies the stroke volume of heart and causes some loss in cardiac output.
3. Possibility of ventricular fibrillation will be more.

### Ventricular synchronous pacemaker (standby pacemaker):

This is used for patients with only short periods of AV block or bundle block. This type does not complete with the normal heart activity. A single transverse electrode placed in the right ventricle both senses R wave and delivers the stimulation.

Thus, no separate sensing electrode is required. R wave triggers ventricular synchronized pacemaker which provides an impulse falling in lower part of normal QRS complex. Atrial generated ventricular contractions generate R wave. Impulses are provided only when the atrial generated ventricular contractions are absent.



**Fig 3.1.3: Ventricular synchronous pacemaker**

#### Working:

Using the sensing electrode heart rate is detected and is given to the timing circuit in pacemaker. If the detected heart rate is below a minimum level the fixed rate pacemaker is turned on. If natural contraction occurs asynchronous pacer's timing circuit is reset so that its next pulse will detect heartbeat. Otherwise, asynchronous pacemaker produces at its preset rate. The pacemaker may detect noise and interpret as its ventricular excitation. This can be eliminated by refractory period or gate circuit. In heart blocks P waves with respect to ventricular excitation. P and R waves have different frequency bands. The high pass filter completely eliminates P-waves and the R-waves. Input amplifier increases peak-to-peak amplitude of R-wave.

#### Advantages:

- It can be used to arrest ventricular fibrillation
- If the R-wave occurs with its normal value in amplitude and frequency then it would not work. Hence the power consumption is reduced and no side effects.
- When the R-wave is appearing with lesser amplitude
- If the R-wave amplitude is too low or too high the asynchronous pacer works to return

the heart in to normal one.

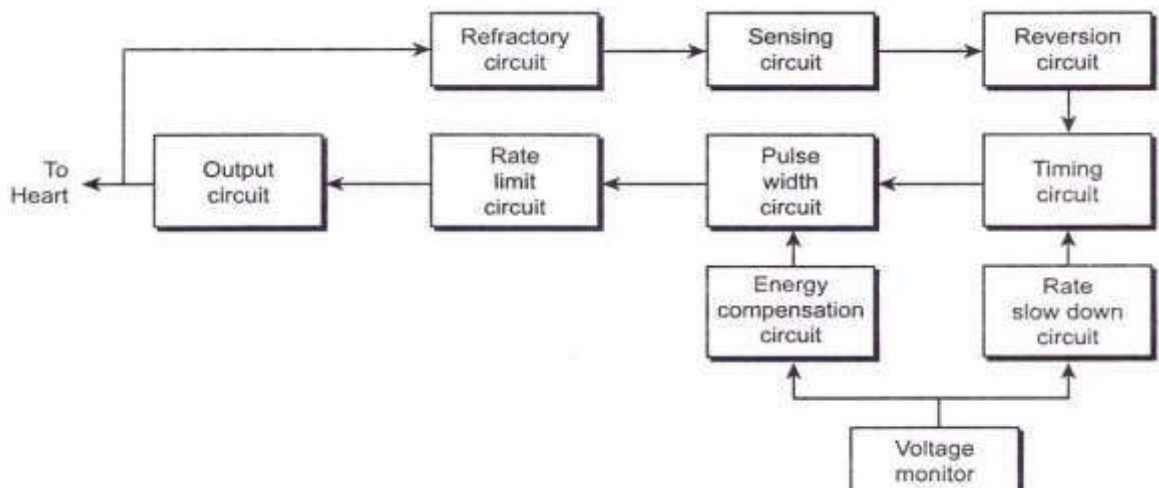
### Disadvantages:

- Atrial and ventricular contractions are not synchronized.
- In olden type pacemaker the circuit is more sensitive to external electromagnetic interference.

### Ventricular inhibited pacemaker (Demand pacemaker):

It is also known as R-wave inhibited pacemaker. If the normal heart rate falls below minimum the pacemaker will turn on and provide the heart a stimulus. Hence it is called as **Demand pacemaker**.

There is a piezoelectric sensor shielded inside the pacemaker. When the pacemaker can automatically increase or decrease its rate. Thus it can match with greater physical effort. The sensing electrode pick up R-wave. The refractory circuit provides a period of time for the sensed R-wave. The sensing circuit detects the R-wave resets the oscillator. The reversion circuit allows the amplifier to detect R wave in the low level SNR. IN the absence of R wave oscillator in timing circuit delivers pulses at its preset rate. The timing circuit determines the pulse rate of pulse generator. The output of timing circuit is fed in to the pulse width circuit which is an RC network. The pulse width circuit determines the duration of pulse delivered to heart. Rate limiting circuit limits the pacing rate to a maximum of 120pulses/min. Output circuit provides a proper pulse to stimulate the heart. The timing circuit, pulse width circuit, Rate limiting circuit and output circuit are used to produce the desired pacemaker pulses to pace the heart.



**Fig 3.1.4: Ventricular inhibited pacemaker**

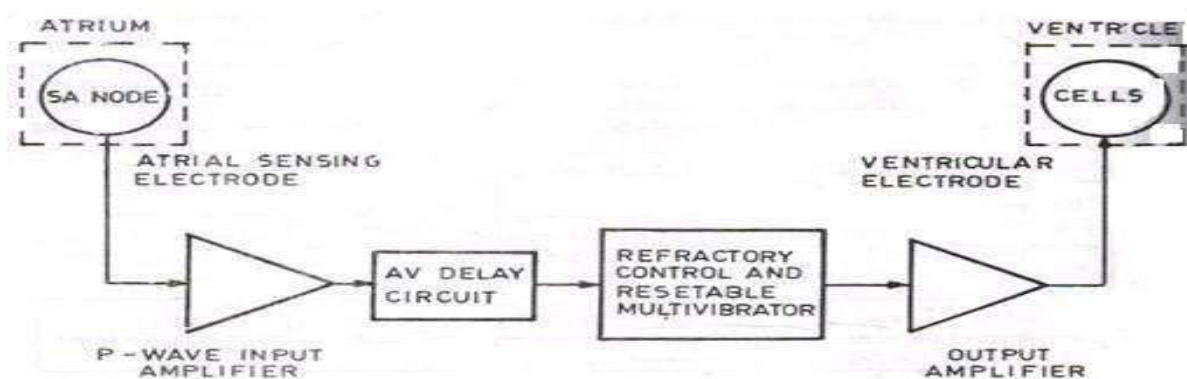
A special circuit called voltage monitor senses the cell depletion and signals in rate slow down circuit energy compensation circuit. The rate slowdown circuit shuts off some of the current to timing network to slowdown  $8\pm 3$ beats/min during cell depletion. The energy compensation circuit increases the pulse duration to maintain constant simulation energy to heart.

### **Atrial synchronous pacemaker:**

It is used for young patient with a mostly stable block. Atrial pacing is a temporary pacing and has many uses in physiologic investigation. It is used in stress testing and coronary artery diseases. It can act as a temporary pacemaker for atrial fibrillation. The atrial activity is picked up by a sensing electrode placed in the dorsal wall of atrium. The detected p wave is amplified and a delay of 0.12sec is provided by AV delay circuit. The signal is then used to trigger the resettable multivibrator. The output of multivibrator is given to amplifier which produce the desired stimulus to heart. The stimulus is delivered to the ventricle through the ventricular electrode. If the rate of atrial excitation becomes too fast or too slow a preset fixed rate pacemaker is used.

### **Atrial sequential Ventricular inhibited pacemaker:**

It has the capability of stimulating both atria and ventricles. If atrial function falls this pacemaker will stimulate the atrium and then sense the subsequent ventricular beat. If atrial beat is not conducted to ventricle the pacemaker will fire the ventricle at a preset interval of 0.12sec.



**Fig 3.1.5: Atrial synchronous pacemaker**

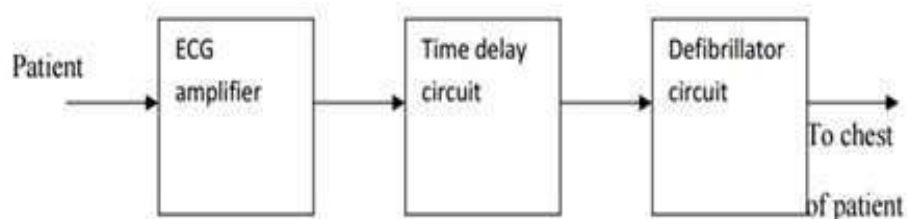


## DC DEFIBRILATOR

A Defibrillator is an electronic device that creates a sustained myocardial depolarization of a patient's heart in order to stop ventricular fibrillation or atrial fibrillation. Ventricular fibrillation is a serious cardiac emergency resulting from asynchronous contraction of heart muscles. This results from electric shock or abnormalities of body chemistry. Hence it causes a steep fall of cardiac output and can lead to death if adequate steps are not taken promptly. Ventricular fibrillation can be converted to a more efficient rhythm by applying a high voltage shock to the heart. This voltage causes all muscle fibers to contract simultaneously. The instrument for administering the electric shock is called defibrillator. The sudden cardiac arrest can be treated using a defibrillator and 80% of patient's will be cured if the treatment is given within one minute of attack.. An atrial fibrillation causes reduced cardiac output but is usually not fatal. It happens for the young people who are always smoking and can even be cured by drug therapy.

### DC DEFIBRILLATOR WITH SYNCHRONIZER

- Synchronization means, synchronized the working of the heart with the pacemaker. Synchronized DC defibrillator allows the electric shock at the right point on the ECG of the patient.
- Electric shock is delivered approximately 20 to 30 ms after the peak of R wave of patient's ECG.



**Fig 3.2.1: Block Diagram of DC Defibrillator With Synchronizer**

### Working



- ECG waveform is traced from the patient.
- R-wave in the output of ECG amplifier triggers the time delay circuit .It gives the delay of 30 ms approximately. After that, defibrillator circuit is switched ON. So that, the capacitor discharges the electric shock to the patient's heart.
- The moment at which electric shock occurs is noted by producing the marker pulse on monitoring display.
- This type of circuit is preferred in cardiac emergencies.
- The sudden cardiac arrest can be treated using a defibrillator and 80 percent of the patients will be cured from the cardiac arrest if the is given within one minute of the attack.

### **Electrodes used for defibrillation**

- These paddles have metal disks of 8 to 10 cm in diameter for external use.
- For internal use smaller paddles are used on infants and children.
- For external use, pair of electrodes are firmly pressed against the patients chest.

### **Need of Insulation Handle**

- To prevent the person applying the electrodes from accidental electric shock specially insulated handles are provided in the paddles.
- When paddles are properly positioned , this prevents the patient from receiving a shock.
- In earlier equipment a foot switch is used instead of thumb switch.

### **Need of Thumb Switch**

There is a possibility of someone accidentally stepping on the foot switch in the excitement of an emergency before the paddles are placed. So thumb switches are mostly preferred.

### **Charging of Defibrillators**

In some defibrillators charging is done by means of a charge switch located in the front panel of the unit. The charge switch is located in the handle of one of its paddles. In few defibrillators the charging process begins automatically after discharge.

### **Types of Electrodes**

Two electrodes are

- Anterior-anterior
- Anterior-posterior

Anterior-anterior paddles are applied to the chest. Anterior-posterior paddles are applied to both the patient's chest wall and back so that energy is delivered through the heart. Specially designed pediatric paddles are available with diameter ranging from 2 to 6 cm. Internal paddles can be either gas-sterilized or autoclaved.

### **Indication Meter**

Most of the defibrillators include a watt second meter to indicate the amount of energy stored in the capacitor before discharge. The energy indicated on the meter is lost or dissipated as heat in the components inside the unit.

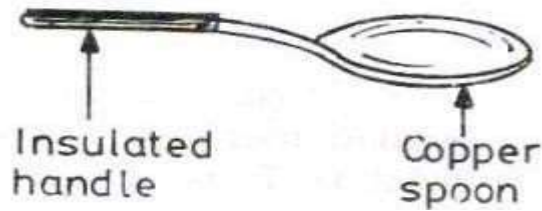
### **Types of defibrillators:**

There are two types of defibrillators based on electrodes placement

- (i) Internal defibrillator
- (ii) External defibrillator

### **Internal Defibrillator:**

It is used when the chest is opened. It uses large spoon shaped electrodes with insulated handle. Since the electrodes are in direct contact with heart the contact impedance is about  $50\Omega$ . The current passing through the heart is of 1 to 20A.

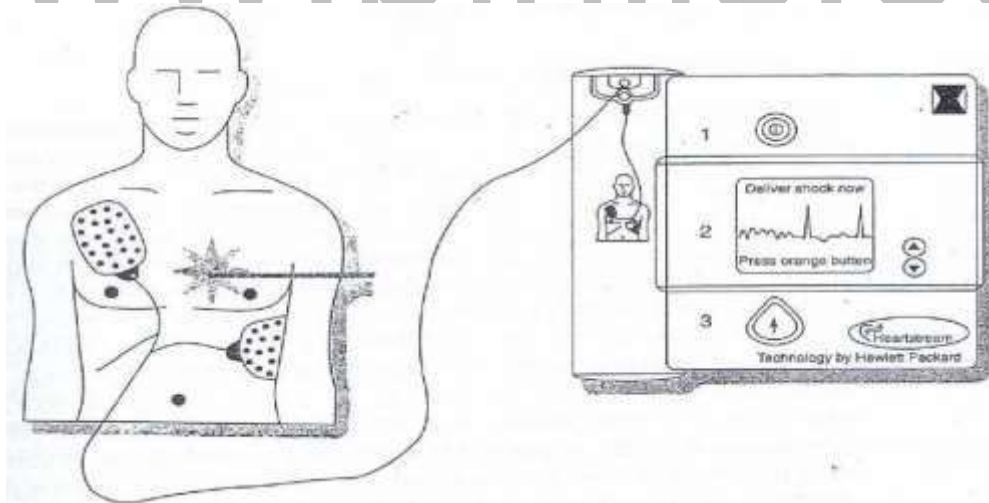


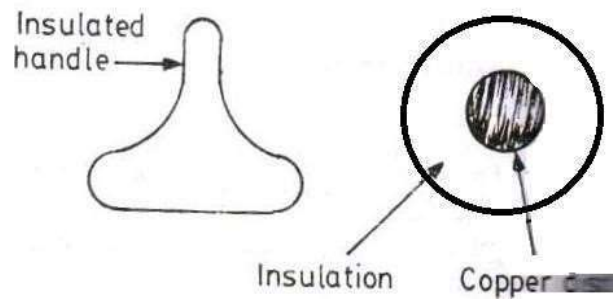
**Fig 3.2.2: Spoon Shaped Electrode**

[Source: John G. Webster, -Medical Instrumentation Application and Design]

### External defibrillator:

External defibrillator is used on the chest using paddle shaped electrodes. The bottom of the electrode consists of a copper disc and is attached with highly insulated handle. The required voltages are from 1000 to 6000V. when the electrodes are placed on the chest after the application of electrode gel the contact impedance on the chest is about  $100\Omega$ . The d.c defibrillator is designed to deliver 50 to 400J of energy through thorax. The duration of shock is about 1 to 5ms. The current flowing through the chest is about 10 to 60A.





**Fig 3.2.3: Paddle Shaped Electrode**

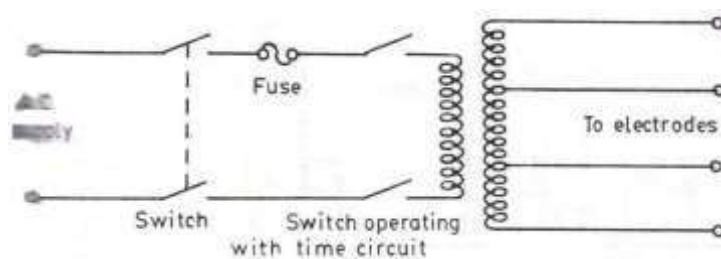
[Source: John G.Webster, -Medical Instrumentation Application and Design]

Depending upon the nature of voltage applied the defibrillators can be divided in to six groups.

1. A.C defibrillator
2. D.C defibrillator
3. Synchronized D.C defibrillator
4. Square pulse defibrillator
5. Double square pulse defibrillator
6. Biphasic D.C defibrillator

#### 1. A.C defibrillator:

It is the earliest and simplest type of defibrillator. It has appropriate voltages for both internal and external defibrillation. It consists of a step-up transformer with various tappings on secondary side.



**Fig 3.2.4: A.C defibrillator**

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

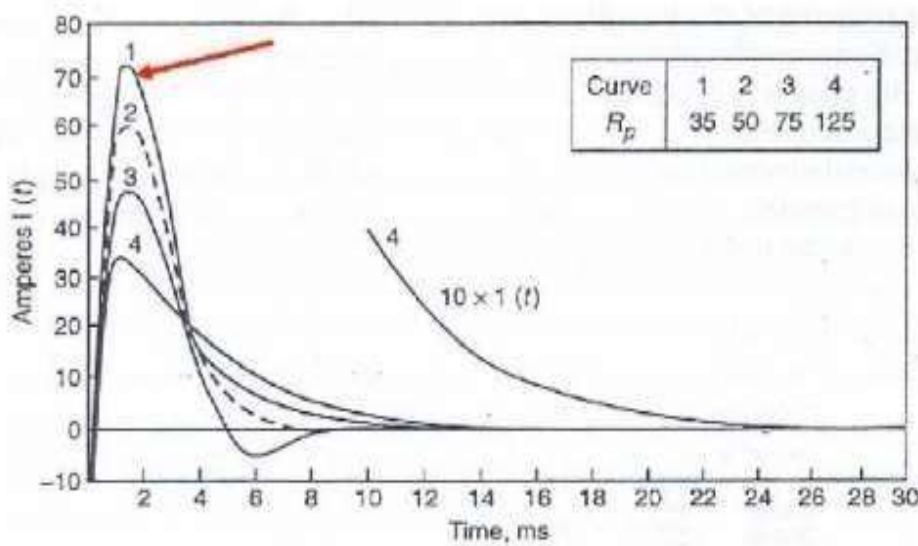
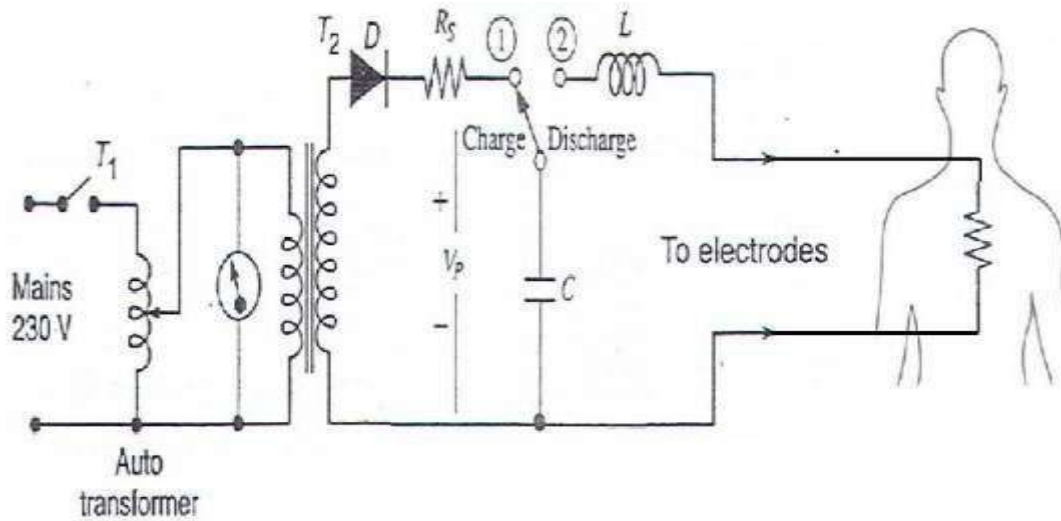
An electronic timer circuit is connected to the primary of the transformer . The timer

connects the output of the electrodes for a preset time. The timing device may be simple capacitor and resistor network which is triggered by a push button switch. The duration of shock may vary from 0.1-1sec depending upon the voltage to be applied. For safety the secondary coil of transformer should be isolated from earth so that there is any shock risk to anyone. For external defibrillation the voltages are in the range from 250 to 750V. For internal defibrillation the voltage is from 60 to 250 V. External defibrillation requires large currents for the simultaneous contraction of heart muscle fiber. This current also results in occasional burning of skin under the electrodes. Further it produces atrium fibrillation while arresting ventricular fibrillation.

## 2. D.C defibrillator:

D.C defibrillator would not produce undesirable side effects and at the same time it produces normal heart beat effectively. Ventricular fibrillation is terminated by passing a high energy shock through discharging a capacitor to exposed heart or chest of patient. A variable auto transformer T1 forms the primary of a high voltage transformer T2. The output voltage of transformer T2 is rectified by a diode rectifier and is connected to a vacuum type high voltage change over switch. In position A the switch is connected to one end of an oil filled capacitor.

In this position the capacitor charges to a voltage set by the positioning of auto transformer. During the delivery of shock to patient a push button switch mounted on handle of electrodes operated. The high voltage switch changes to position B and the capacitor is discharged across the heart through electrodes. An inductor L is placed in one of the electrode leads so that the discharge from the capacitor is slowed down by the induced counter voltage. The shape of waveform that appears across the electrodes will depend upon the value of capacitor and inductor and it's the amplitude depends upon the discharge resistance. The success of defibrillation depends upon the energy stored in the capacitor and not with the voltage used. For internal defibrillation 100J of energy is required where as for external defibrillation 400J are required. The discharging duration is from 5ms to 10ms.

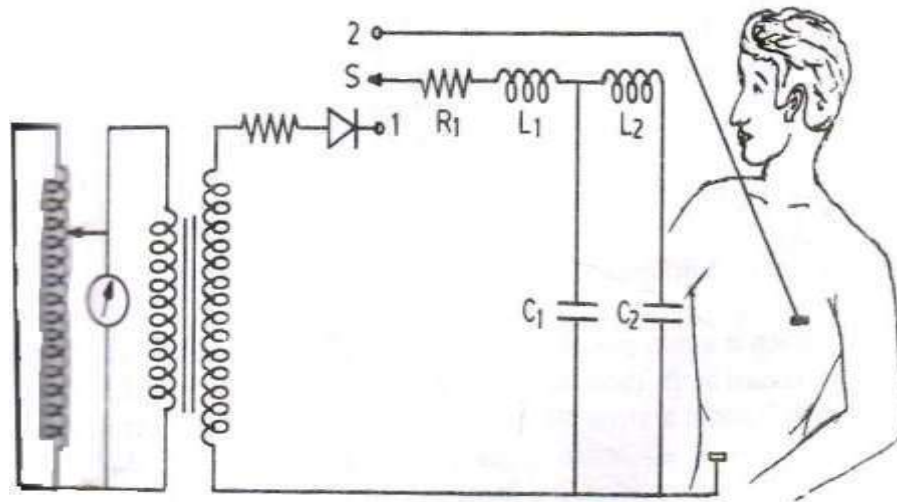


**Fig 3.2.5: D.C defibrillator(ordinary type) and its output**

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

### Dual peak d.c defibrillator:

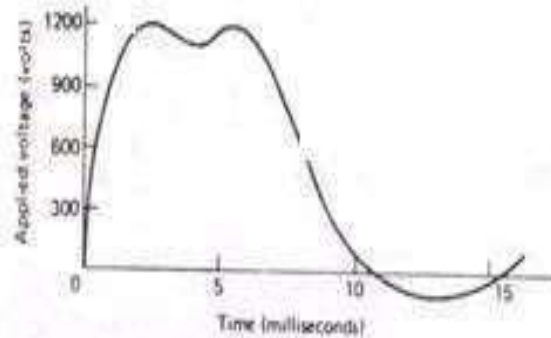
The passage of high current may damage the myocardium and the chest wall. To reduce this risk some defibrillators produce dual peak waveform this keeps the stimulus at peak for longer duration. Some energy can be applied to the heart with low current level such defibrillators are called dual peak defibrillators or delay line capacitance discharge d.c defibrillators.



**Fig 3.2.6 (a): Dual peak d.c defibrillator**

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

[www.binils.com](http://www.binils.com)



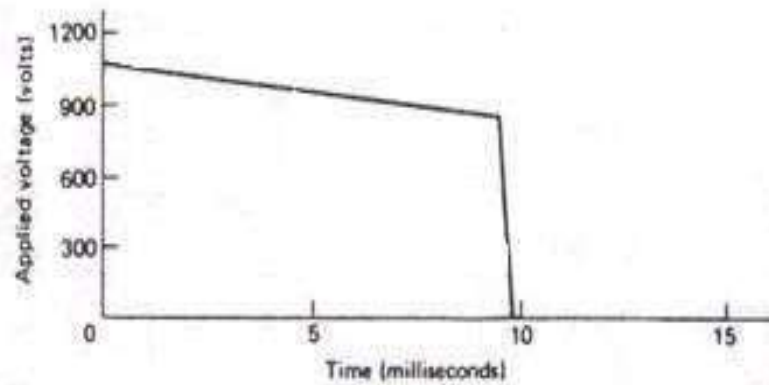
**Fig 3.2.6 (b): output of Dual peak d.c defibrillator**

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

### Truncated defibrillator:

In this type the capacitor discharge is adjusted so that the effective defibrillation is obtained at the desirable low voltage level. The voltage level of the wave is almost constant but its duration is extended to obtain the required energy.



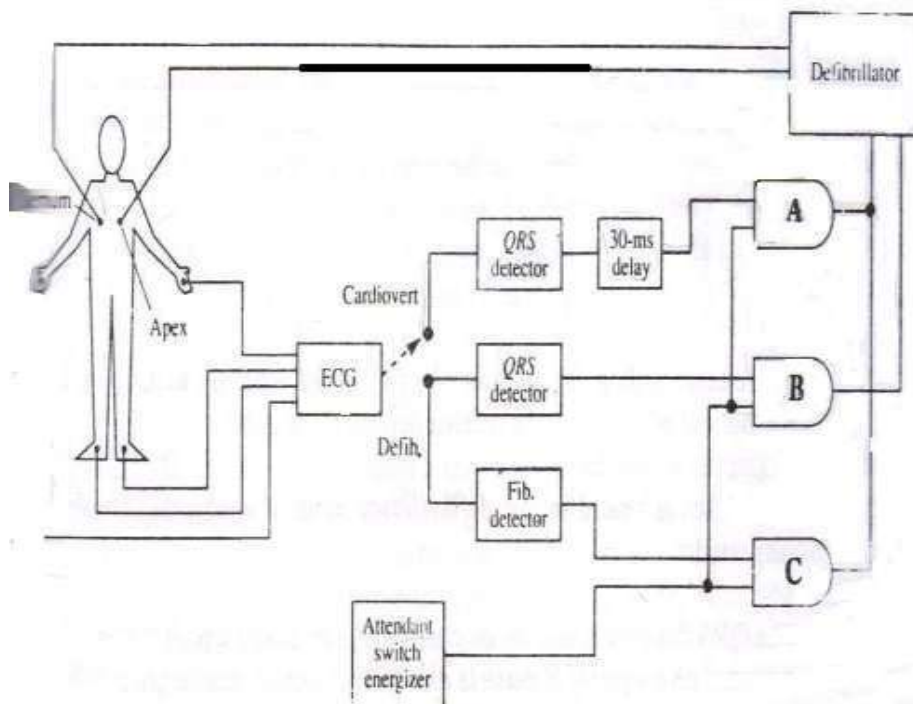


**Fig 3.2.7: Truncated defibrillator discharge waveform**

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

### 3. Synchronized D.C defibrillator:

Defibrillator is a risky procedure since if it is applied incorrectly it could induce fibrillation in a normal heart. It is essential to use a defibrillator with synchronizer circuit. There are two zones in a normal cardiac cycle. T wave and U wave segments. If the counter shock falls in the T wave segment then the ventricular fibrillation is developed. If the counter shock falls in the U wave segment then the atrial fibrillation is developed.



### Fig 3.2.8 : Modern d.c defibrillator circuit

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

Fig shows the modern d.c defibrillator circuit consisting of defibrillator electrocardioscope and pacemaker. The pacemaker is used in case of emergency as a temporary pacing. It includes

a) Diagnostic circuitry used to assess the fibrillation before delivering the defibrillation pulse.

b) Synchronizer circuitry used to deliver the defibrillation pulse at the correct time so as to eliminate the ventricular or atrial fibrillation without inducing them.

#### Working:

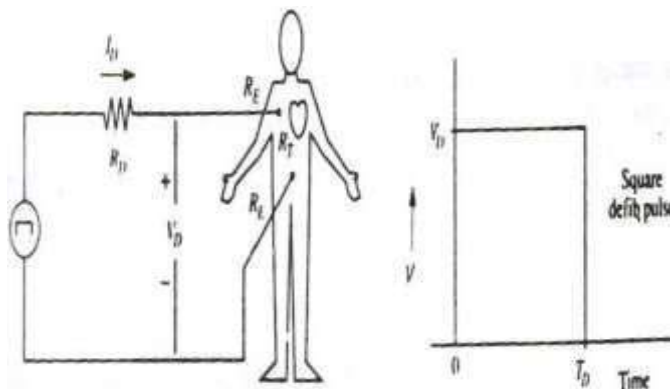
1. The electrocardiogram is obtained by means of an ECG unit connected to the patient who is going to receive defibrillation pulse.
2. The switch is placed in the defibrillator mode if ventricular fibrillation is suspected.
3. The QRS detector in that mode consists of a threshold circuit that would pass the signal as output if R wave is almost in electrocardiogram. Otherwise it would not give any output if wave is present.
4. Meanwhile the medical attendant energizes the switch to deliver the defibrillation pulse.
5. AND gate B delivers signal to the defibrillator only when the R wave is absent, provided the signal from medical attendant is also present at one of the two inputs of AND gate B.
6. If any one of the input is missing then it would not give any output. By this way defibrillator is inhibited and would not deliver the defibrillation pulse.
7. The fibrillation detector searches the ECG signal for frequency components above 150Hz. If they are present fibrillation is probable and detector gives an output signal. A defibrillator pulse is delivered only if the fibrillation detector produces an output at the same time that the attendant energizes the switch. This is provided by the AND gate C.

8. When AND gate  $\underline{B}$  and  $\underline{C}$  are simultaneously triggering the defibrillator the defibrillation pulse is delivered.
9. In cardio version (or) synchronization mode the defibrillator is synchronized with ECG unit. Suppose a patient is suffered by atrial fibrillation the doctor first diagnose it correctly and then the treatment is initiated using this circuit.
10. The ECG signal is given to QRS detector Its output is delayed with 30ms. At this time the ventricles will be in uniform state of depolarization and the normal heart beat will not be disturbed. The delay of 30ms after the occurrence of R wave allows the attendant to defibrillate atrium without inducing ventricular fibrillation.

#### 4. Square wave defibrillator:

Here the capacitor is discharged through the subject by turning on a series silicon controlled rectifier (SCR). When sufficient energy has been delivered to the subject a shunt SCR short circuits the capacitor and terminates the pulse. The output can be controlled by varying the voltage on capacitor or duration of discharge. Defibrillation is obtained at less peak current and so there is no side effect.

#### Analysis:



**Fig 3.2.9: Equivalent circuit of square pulse defibrillator and its output waveform**

[Source: Leslie Cromwell, —Biomedical Instrumentation and Measurement]

In fig

$R_D$ -Internal resistance of defibrillator

$R_E$ -electrode skin resistance

$R_T$ -Thorax resistance

The energy in the pulse

$$EP = V_D I_D T_D$$

Where

$V_D I_D$ -Instantaneous voltage and current available from defibrillator pulse

$T_D$ -Duration of pulse

Total circuit resistance

$$R = R_D + 2R_E + R_T$$

Energy in the pulse can also be written in terms of voltage and resistance between the cable attached to patient such that, The energy delivered to the thorax can be expressed in the form of available energy from capacitor discharge whose output is assumed to be a square pulse.

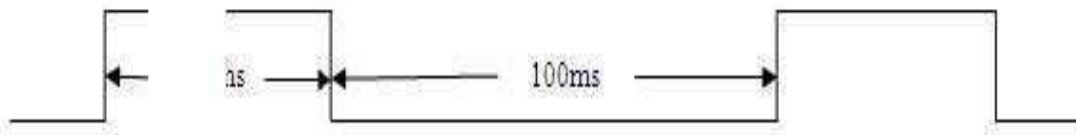
Energy available from the capacitor

$$EC = E_T + 2 E_{EL} + E_{DL}$$

Thus  $E_T$  is dismissed from available due to effects of  $R_D$  and  $R_E$ .

### 5. Double Square Pulse Defibrillator:

It is used normally after the open heart surgery. Conventional A.C and D.C defibrillators are producing myocardial injury during the delivery of shock. If the chest is opened only lower energy electric shock should be given. Instead of 800-1500V in D.C defibrillators here 8-60V double pulse is applied with a mean energy of 2.4 watt-sec. When the first pulse is delivered some of fibrillating cells will be excitable and will be depolarized.



**Fig 3.2.10: Double Square Pulse Defibrillator output waveform**

Also cells which are refractory will continue to fibrillate. To obtain total defibrillation

second pulse operates on this latter group of cells. The pulse amplitude and width together with interval should be such that the cells defibrillated by first pulse will be refractory to second pulse. The timing of second pulse should be such that those cells which were refractory to the first pulse are now excitable. Thus complete defibrillation can be obtained by means of selecting proper pulse space ratio.

**Advantages:**

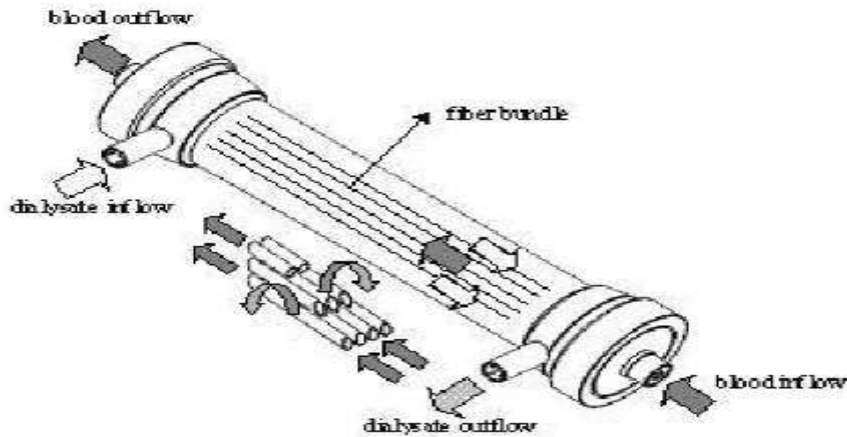
- Using double square pulse defibrillator efficient and quick recovery of heart to beat in normal manner without side effect like burning of myocardium or inducement of atrial or ventricular fibrillation.
- The double square pulse with required pulse space ratio can be produced with the use of digital circuits.

**6. Biphasic D.C defibrillator:**

It is similar to double square pulse defibrillator such that it delivers D.C pulses alternatively in opposite direction. This type of waveform is found to be more efficient for defibrillation of ventricular muscles.

## Hemodialyser

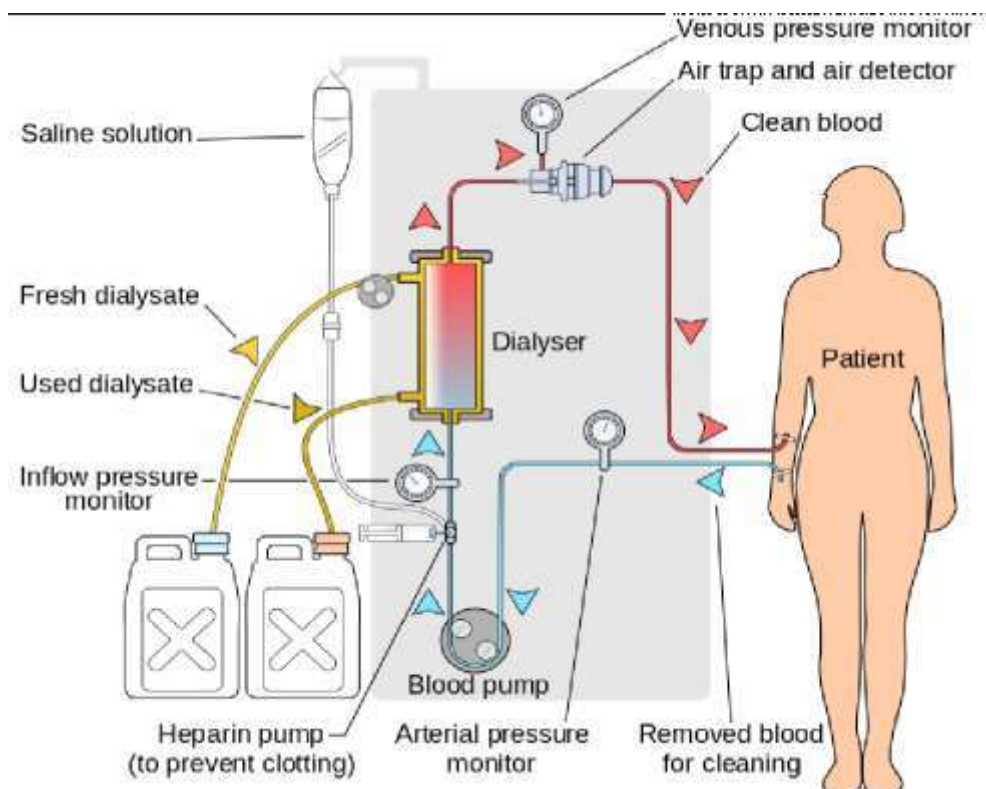
Hemodialysis, also called dialysis, is the most common treatment for kidney failure.



**Fig 3.3.1: Dialyser Internal Diagram**

[Source: Joseph J.Carr and John M.Brown, —Introduction to Biomedical Equipment Technology]

During dialysis, blood is drawn from the patient into the dialysis machine, circulated through the machine, and then returned to the patient. Two needles are inserted into the patient's bloodstream to allow this process to occur.



### **Fig 3.3.2: Simplified Hemodialysis Circuit**

[Source: Joseph J.Carr and John M.Brown, —Introduction to Biomedical Equipment Technology]

Hemodialysis is normally performed three times a week and the purpose of vascular access is to provide reliable sites where the bloodstream can be easily accessed each time. There are three major types of vascular access: arteriovenous fistula, arteriovenous graft, and venous catheter. The great majority of vascular accesses are created in the arm, but they can also be created in the leg.

#### **Types of Vascular Access**

The three most common types of access are: ,,

- Internal arterio-venous fistula (AV fistula) ,,
- Internal arterio-venous graft (AV graft) ,,
- Central venous catheter (also called central venous –line or hemodialysis catheter)

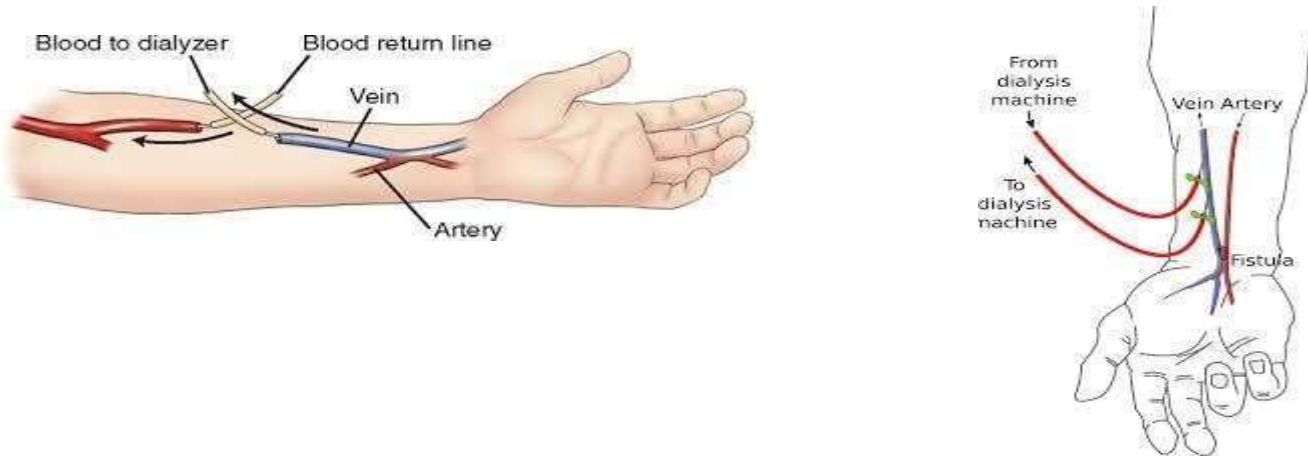
#### **1. Arteriovenous Fistula**

A surgeon creates an arteriovenous fistula by making a connection between an artery (which carries blood away from the heart) and a vein (which carries blood back to the heart). This artificial connection allows the vein to become larger and for the walls of the vein to thicken, a process termed maturation. A mature fistula makes it easier for the vein to be punctured repeatedly for dialysis. Maturation typically takes three to six months to occur, but in rare cases, can take up to a year. This makes advance planning for an arteriovenous fistula important. When a patient is felt to be approximately a year away from requiring dialysis, the patient should be referred for evaluation for possible creation of an arteriovenous fistula.

An arteriovenous fistula is the preferred type of vascular access due to lower rate of infection and clot formation, resulting in greater longevity than other types of vascular access. However, not everyone is a good candidate for an arteriovenous fistula, particularly older patients and patients with small veins.

Apprise Education, Reprise Innovations



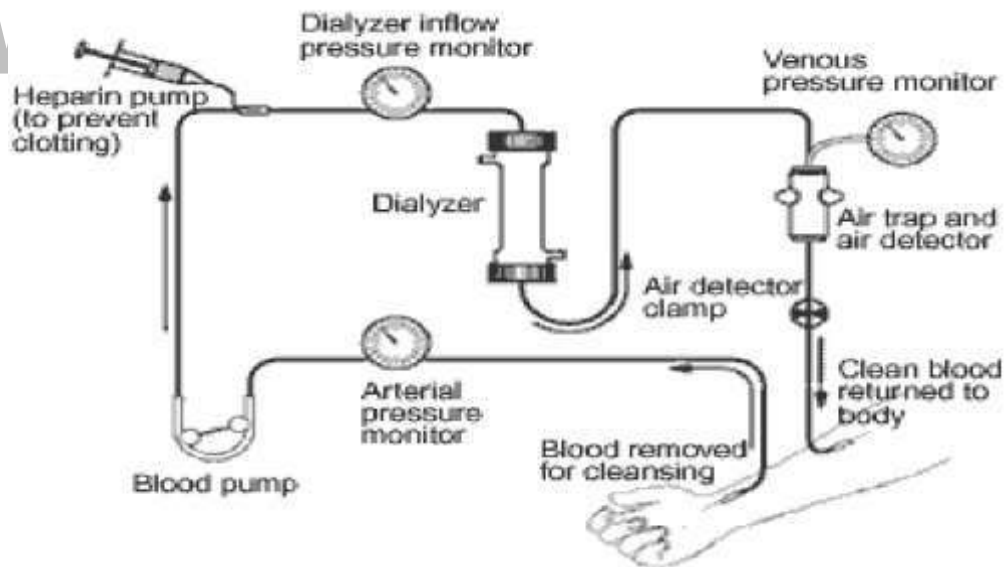


**Fig 3.3.3: Arteriovenous Fistula**

[Source: Joseph J.Carr and John M.Brown, —Introduction to Biomedical Equipment Technology]

## 2. Arteriovenous Graft

If a patient is not a good candidate for an arteriovenous fistula, an arteriovenous graft is considered. An arteriovenous graft is a piece of artificial tubing, generally made out of Teflon or fabric, that is attached on one end to an artery, and on the other end to a vein.



**Fig 3.3.4: Arterio-Venous Graft (AVG)**

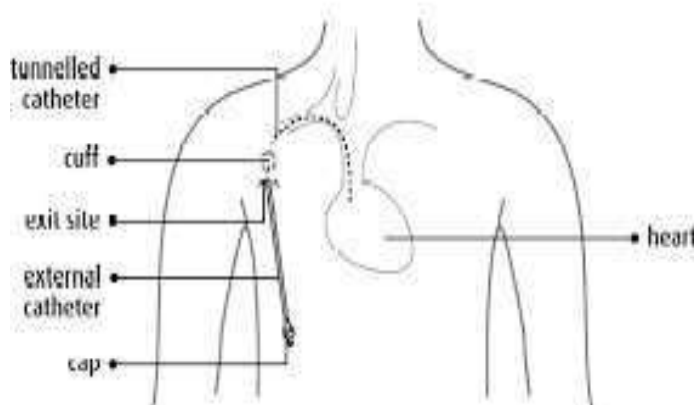
[Source: Joseph J.Carr and John M.Brown, —Introduction to Biomedical Equipment Technology]

The tube is placed entirely under the skin and the tube itself is punctured during dialysis. An arteriovenous graft can in general be used two to three weeks after the operation. However, arteriovenous grafts are more prone to infection and clotting than fistulas. The lifespan of an arteriovenous graft is approximately two to three years.

### 3. Venous Catheter

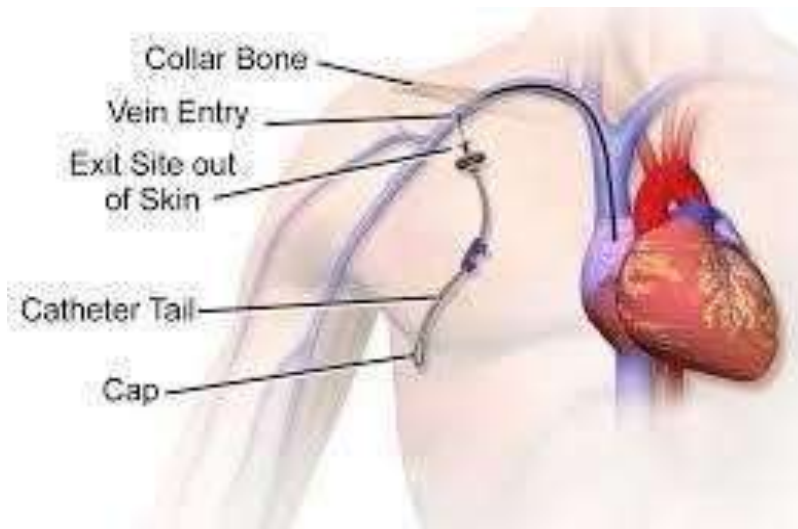
A third type of vascular access is a venous catheter. A venous catheter is a plastic tube which is inserted into a large vein, usually in the neck. An external portion of the catheter is exposed on the chest wall that allows the tubing for the dialysis machine to be connected. Because the catheter is not entirely under the skin, it is prone to infection. Venous catheters also have a high rate of becoming clogged and do not provide for as efficient dialysis as fistulas and grafts.

Venous catheters are generally considered temporary vascular accesses, and are usually only placed when urgent dialysis is needed. In rare cases, a venous catheter may be used as long-term vascular access if no other options are available



**Fig 3.3.5: Tunneled central Venous Catheter**

[Source: Joseph J.Carr and John M.Brown, —Introduction to Biomedical Equipment Technology]



**Fig 3.3.6: Non-Tunneled Central Venous Access Device**

[Source: Joseph J.Carr and John M.Brown, —Introduction to Biomedical Equipment Technology]

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## Magnetic resonance imaging:

- Magnetic resonance imaging (MRI) is a medical imaging technique used in radiology to form pictures of the anatomy and the physiological processes of the body.
- MRI scanners use strong magnetic fields, magnetic field gradients, and radio waves to generate images of the organs in the body.
- Compared with CT scans, MRI scans typically take longer and are louder, and they usually need the subject to enter a narrow, confining tube.

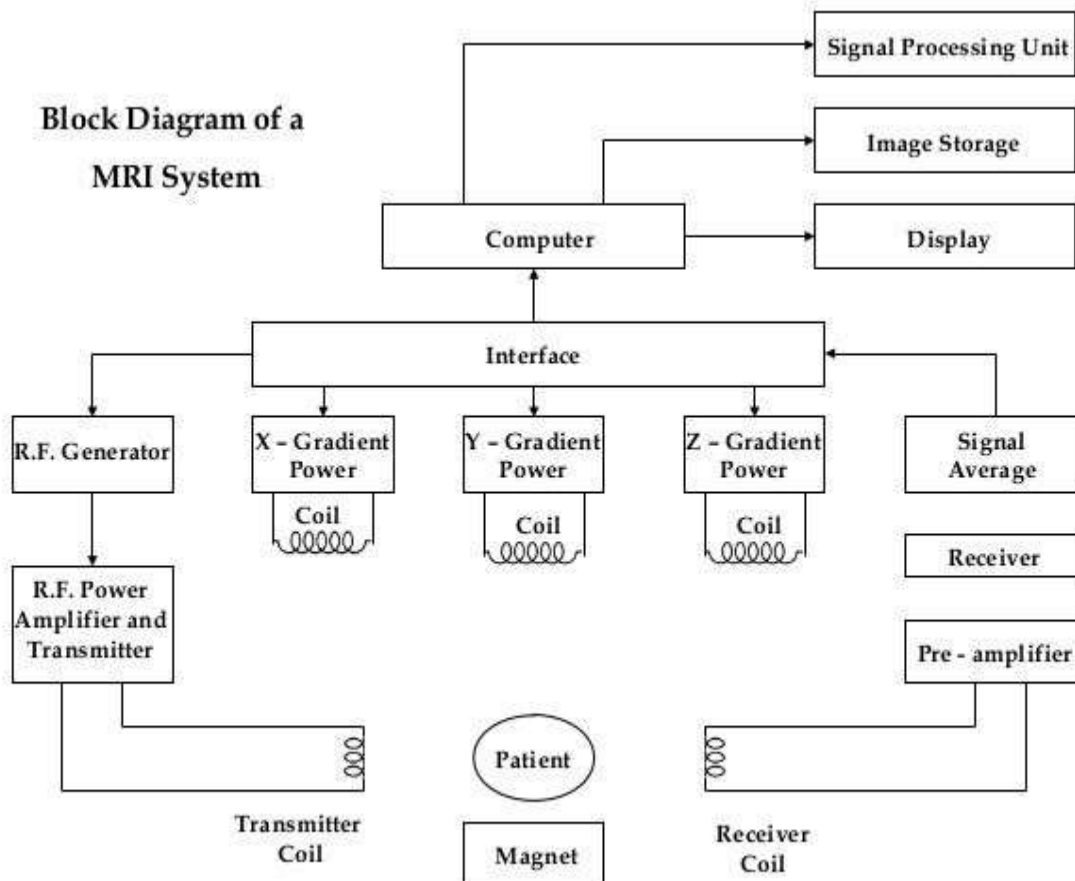


Fig: Block diagram of MRI System

Source:Tutorial point

- The block diagram consist of super conducting magnetic coil, RF transmitter and receiver coil (X,Y,Z gradient coil), computer and display unit. There is superconducting magnetic coil which provides a strong uniform steady magnetic fields and the coils are used to cooled to liquid helium temperature and it can produce very high magnetic field.
- Therefore SNR (signal to noise ratio) of the received signals and image quality are better than the conventional magnets used in MRI system.
- Different gradient coils (XYZ) systems produce a time varying controlled spatial non uniform magnetic fields in different direction.
- By taking a series of these projections at different direction a two or three dimensional image can be obtained.
- Now the patient is kept in this gradient filed space between the transmitter and receiver RF coils surrounding the site on which the image is to be constructed.
- A superposition of a liner magnetic field gradient on to the uniform magnetic field is applied to the patient.
- When the superposition takes place, the resonance frequencies of the processing nuclei depend primarily and produces a one dimensional projection of the structure of the three dimensional object.
- The slice of image depends upon the gradient magnetic field is controlled by computer and that field can be positioned in three time invariant planes ie (X Y and Z)

- The transmitter provide the RF signal pulses and the received nuclear magnetic resonance signal is picked up by the receiver coil and is fed into the receiver for signal processing.
- By using two dimensional fourier transformation, the image is constructed by the computer and displayed on screen.

**Advantages:**

- Superior contrast resolution
- Direct multiplaner imaging
- Non invasive imaging technique

**MRI parameter:**

There are three MRI parameters they are

- Spin density
- Spin lattice (longitudinal) relaxation time T1
- Spin-Spin (or) Transverse relaxation time T2

### **Ultrasonography / Ultrasonographic imaging system:**

Ultrasound is a form of energy which consists of mechanical vibrations as the frequencies are high, above the range of human hearing. Most biomedical applications of ultrasound employ frequencies in the range of 1 to 15 MHz. The velocities of ultrasound in tissues and bones are 1570 m/sec and 3600 m/sec respectively.

Ultrasonic diagnostics is based on

- ❖ Echo aspect
- ❖ Doppler shift aspect

Ultrasonic Therapeutic aids are based on

The thermal effect

Cavitations effect (developed during the irradiation of the body)

### **Doppler Ultrasonic Blood flow meter**

It is used to determine the flow rate of blood in various blood vessels

It can cure the cancer and also used to detect the ordinary benign tumors.

The ultrasonic are used to fix the fractured bones at their proper place in their body.



## ULTRASONOGRAPHY

In this technique ultrasonic energy is used because it is used to detect the state of internal body organs. When the energy strikes an interface between two tissues of different acoustical impedance, reflection (echoes) are returned to the transducer.

The transducer converts these signals to electrical signals. This echo signal is amplified and displayed on the oscilloscope of the distance proportional to the depth of the interface.

### BLOCK DIAGRAM OF ULTRASONIC IMAGING INSTRUMENTATION

Block Diagram of a Computer Controlled Ultrasonic Image Forming System



Fig: Block diagram of computer controlled ultrasonic image system.

(Source: web)

The ultrasonic image forming system consists of so many peripheral circuits such as a (transducer data, receiver panel control, display unit, image storage, and signal processing unit) which are controlled by a computer through control basis.

Computer is the heart of the System. Signal processing unit receives the data from transducer **data** through computer and receiver transducer signal from receiver.

Receiver sensitivity is controlled by the control bus. Proper depth gain compensation is calculated by computer and given to signal processing unit. Like ultra sonic velocity is calculated displayed using display unit.

Past and current status of patient (information data) are stored and explained for detailed examination using ultrasonic imaging technology and the functions are controlled by microcomputer .

But it is difficult to process direct real time image processing. Therefore the high speed analog to digital have enabled for straight digitalization of high frequency signals.

Thus the real-time digital scanners are used for displaying ultrasound images .

## DIGITAL REALTIMESCANNERS

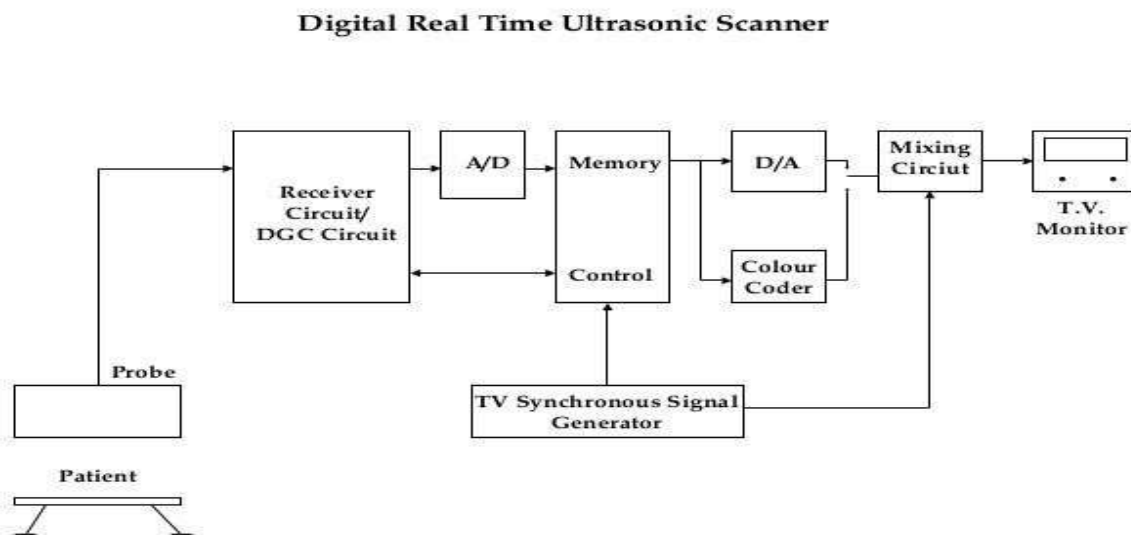


Fig: Block diagram of real time scanner (Source:web )

The block diagram of digital real time scanner consists of receiver/DGC circuit which is used to provide proper depth compensation signal from patient bodies are collected through probe by receiver circuit.

The receiver signals converted into digital signal by using A/D Converter and stored in memory .

Received signals of transducer position ,TV synchronous pulse and generated X and Y information about patients which if fed in memory are collected by scan converter.

The stored digital image signals are processed and color code and the given to digital to analog convertor.

Finally the analog signal is displayed by TV Monitor with high accuracy

DISPLAY:

The reflected echoes are displayed as a useful image in the screen by the following modules

- A- Mode (Amplitude Modulation)
- B- B-Mode(Brightness Modulation)
- C- T-M-M Mode (Time Motion Modulation)

## **APPLICATIONS**

- Ultrasonography are used to find any brain tumor
- Ophthalmology used to find foreign objects in eye.
- Cardiology used to determine the cross section of the heart rate and determine the heart rate gynecology used to indicate the fetus growth and to indicate the presence of twins

LIMITATIONS:

- Bone injury, lung injury and intraluminal injury of GI Track cannot be evaluated
- Ultrasonic cannot penetrate impedance gas and bones due to acoustic impedance mismatch at soft tissue bone (or) soft tissue – gas interface.

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## Ventilators (Respirators)

- Ventilator may be defined as any machine designed to mechanically move breathable air into and out of the lungs to provide the mechanism of breathing for a patient who is physically unable to breathe.
- When artificial ventilation is required for a long time, a ventilator is used to provide oxygen enriched, medicated air to a patient at a controlled temperature.

### Modes of operation:

- There are three different modes and modes differ by which type of inspiration is initiated (i.e) positive and negative.

#### ➤ Negative pressure:

In this design, the flow of air to the lungs is created by generating a negative pressure around the patient's thoracic cage.

The negative pressure moves the thoracic walls outward expanding the intra-thoracic volume and dropping the pressure inside the lungs. The pressure gradient between the atmosphere and the lungs causes the flow of atmospheric air into the lungs.

1. Assist mode
2. Control mode
3. Assist-control mode

#### 1. Assist mode:

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- ❖ Assist mode inspiration is triggered by the patient.
- ❖ Respirator helps the patients when they want to breathe.
- ❖ A sensitivity adjustment is provided to select the amount of patient effort required to trigger the machine.
- ❖ It is used by those who are able to control their breathing but unable to inhale sufficient air without assist.

## **2. Control mode:**

- ❖ Breathing is controlled by a timer set to provide the desired respiration rate.
- ❖ Controlled ventilation is required for patients who are unable to breathe on their own.
- ❖ Respirator has complete control over the patient's respiration.

## **3. Assist-control mode:**

- ❖ The apparatus is normally triggered by the patient's attempt to breathe like assist mode.
- ❖ If the patient fails to breathe within the predetermined time, the timer automatically triggers the device to inflate the lungs, like control mode.

This mode is most frequently used in critical care settings

## **Positive pressure:**

- ❖ Positive-pressure ventilators generate the inspiratory flow by applying a positive pressure (greater than the atmospheric pressure) to the airways.
- ❖ During inspiration, the inspiratory flow delivery system creates a positive pressure in the tubes connected to the patient airway, called patient circuit,

and the exhalation control system closes a valve at the outlet of the tubing to the atmosphere.

The ventilator treatment gives the following.

- **Adequate ventilation** by which enough oxygen is supplied and the right amount of carbondioxide is eliminated.
- **Elimination of respiratory work**
- **Increase intrathoracic** pressure which prevents atelectasis that is collapse of portions of the lung and counteracts edema of the lungs.
- Every ventilators operates cyclically. During insufflation or inspiration air or some other gaseous mixture is pumped into the lungs. During expiration the pressure ceases. This cycle is regulated by mechanical, pneumatic or electronic circuit. The regulation is obtained by **pressure limited, volume limited and servo controlled systems.**

#### **Pressure limited ventilators:**

- Pressure limited ventilators are based on the principle that the insufflation is terminated when the gaseous mixture pumped into the patients lungs reaches a pre-set pressure.
- Pressure limited ventilators are driven by the compressed gaseous mixture used for ventilation.
- These are simple in design and reliable in operation.

#### **volume limited ventilators:**



- This is based on the modern usage of modern electronic control techniques such that the flow to and from the patient is controlled by the feedback circuits.
- The electronic circuit controls the amplifiers and the logic circuits that control the ventilation. It also monitors pressure, activates alarms and computes mechanical lung parameters.
- volume limited ventilators are based on the principle that for each breathe, a constant volume of air delivered. During insufflation, the constant volume of air is sent into the lungs by applying pressure to a chamber containing constant volume.

**servo controlled ventilators:**

- This is based on the modern usage of modern electronic control techniques such that the flow to and from the patient is controlled by the feedback circuits.
- The electronic circuit controls the amplifiers and the logic circuits that control the ventilation. It also monitors pressure, activates alarms and computes mechanical lung parameters.

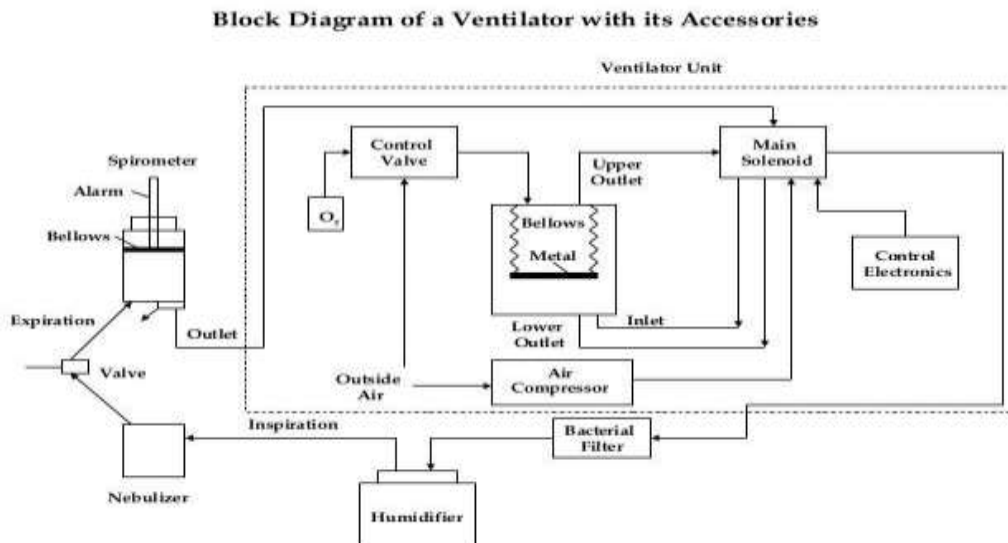
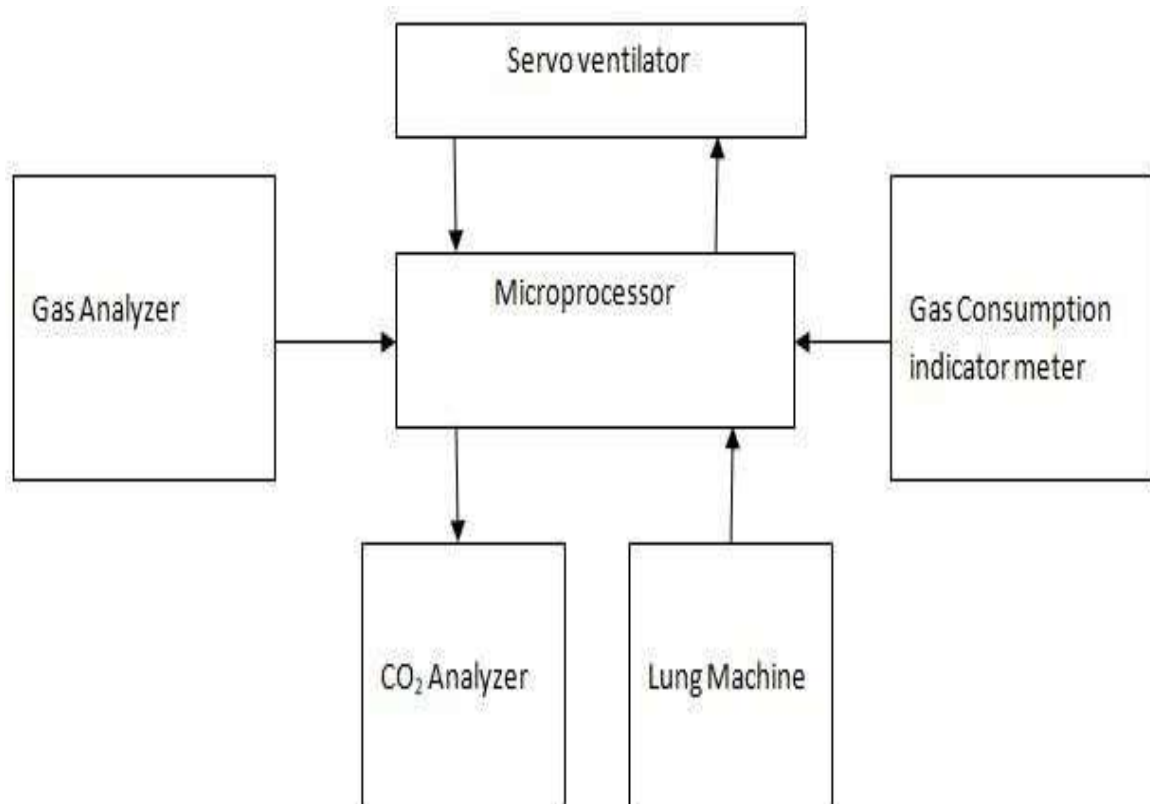


Fig 3. 1: Block Diagram of Ventilators with its accessories

Source: Web

- Figure shows the ventilator unit along with other accessories .
- During patient inspiration, the air compressor draws room air through an air filter and passes it to main solenoid.
- Main solenoid forces the bottom inlet valve of the internal bellows chamber to open and the lower outlet valve to close.
- Oxygen is passed into bellows chamber in a controlled manner by means of a control valve.
- Humidifier: In order to prevent damage to the patients lungs, the applied air or oxygen must be humidified either by heat vaporization or by bubbling an air stream through a jar of water.
- Nebulizer: A nebulizer compressor produces a fine spray of water or medication into the patients inspired air in the form of aerosols . In nebulizer the water or medication picked up by high velocity jet of oxygen enriched air and thrown against one or more baffles or other surface to break the substance into controllable sized droplets which are then applied to patient.
- A sensitivity control monitors the negative pressure necessary to initiate inspiration when the ventilator is used in the assisted mode. An aspirator or other types of suction apparatus is often included as a part of the ventilator to remove mucus and other fluids from the airways.
- When the medicated air forced into lungs through the valve number 1, the spirometer is closed condition. When the inspiration is complete, the main solenoid switches the directions of the pneumatic air to do the expiration cycle.
- Spirometer is used to measure the volume of exhaled air so as to give alarm to stop expiration and to initiate inspiration in the ventilator unit.
- Now a days the microprocessor based control circuits based control circuits are used in ventilator system to improve systems accuracy and reliability.



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- ❖ It can be used as a short term measure.
- ❖ Long term ventilator assistance are required in chronic illness and y be used to home, or in nursing or rehabilitation centre.
- ❖ In positive pressure ventilator additional measure can be required to secure airway .The common employed method is intubation which provides clear route of the air.
- ❖ In negative pressure or non invasive ventilator, there is no need to use any adjunct.