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Department of Biomedical Engineering

Course Name: 19BMB301 Diagnostic & Therapeutic Equipment

III Year : V Semester

Unit I – Cardiac and Neurological Equipment

Topic : Defibrillator


HEARTSTART
First Aid Defibrillator
HEARTSTART
Laerdal
Pull to open
Pull to open


VENTAK
PRIZM 2 DR
GUIDANT

Defibrillation

- As long as the heart tissue contracts concurrently it works as an effective blood pump. But when this concurrency cease to exist some problems begin to emerge.

- One of these problems is the disortion of normal heart rhythm which is called fibrillation. In fibrillation, hearth muscle fibers contract randomly and irregularly instead of contracting smoothly. If ventricles of the heart go in fibrillation state it is called ventricular fibrillation and if atria of the heart go in fibrillation state it is called atrial fibrillation.
- If the heart is in atrial fibrillation it can continue to pump blood because ventricles continue to contract maintaining the blood pressure. But if it is in ventricular fibrillation it can not continue pumping blood. In this situation patient dies after few minutes if no preventive action is taken.

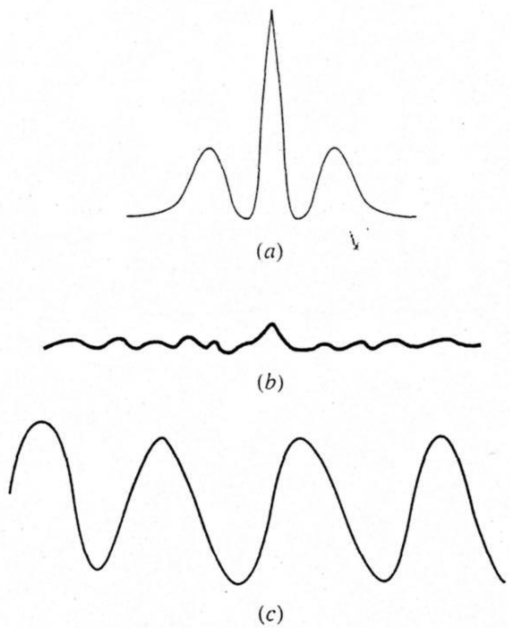
Arrhythmias: SA Block

Figure 4.9 The sinus node activation does not appear on the ECG. The vertical lines indicate sinus node activation instants. During 1˚ SA block there is a delay between sinus node activation and atrial activation. During 2:1 SA block the abnormality cannot be distinguished from sinus bradycardia. In third degree block only the ventricular escape rhythm is recorded. From Chou, T. C. 1986. *Electrocardiography in clinical practice*. 2nd Ed. Grune & Stratton.

- Figure 4.1 shows two **arrhythmia** and one no

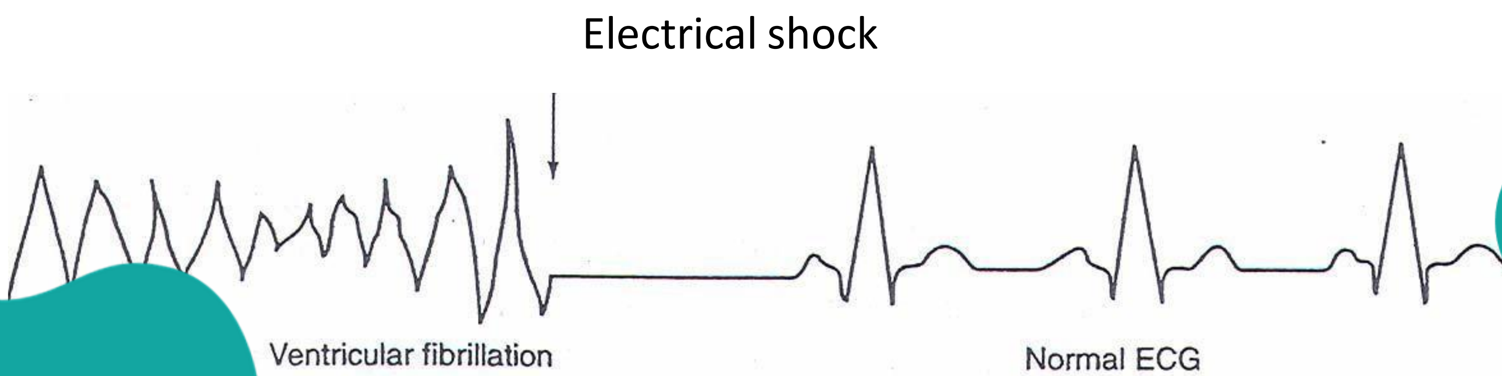
  4.1a is normal rhythm. 4.1b is ventricular fibrillation and 4.1c sh

  ventricular tachycardia



) Normal waveform b) ventricular fibrillation c) ventricular tachycardia

- These arhythmia can be corrected by delivering an electrical s the heart. Electrical shock forces all heart muscle fibres to contract at the same time causing them to enter relaxation period together. As a result correcting the rhytm to normal rhythm.



Defibrillators

Defibrillators are devices that deliver electrical shock to heart muscles in order to restore normal hearth rhythm from arrhythmia state.

The first devices were using AC current.

- They were not efficient.
- They were not usable in atrial fibrillations
- Trying to treat atrial fibrillation with AC shock usually results in more dangerous ventricular fibrillation.

• To solve this DC defibrillators were developed. These devices deliver DC current waveforms (DC Shock) to the patient in order to treat fibrillation.

Defibrillators

- The *defibrillator* is a device that delivers electric shock to the heart muscle undergoing a fatal arrhythmia.
- Electric shock can be used to reestablish normal activity
- Four basic types of Defibrillators
  - AC Defibrillator
  - DC Defibrillator

DC types

- 1- lown
- 2- monopulse
- 2- tapered (dc) delay
- 3- trapezoidal wave.

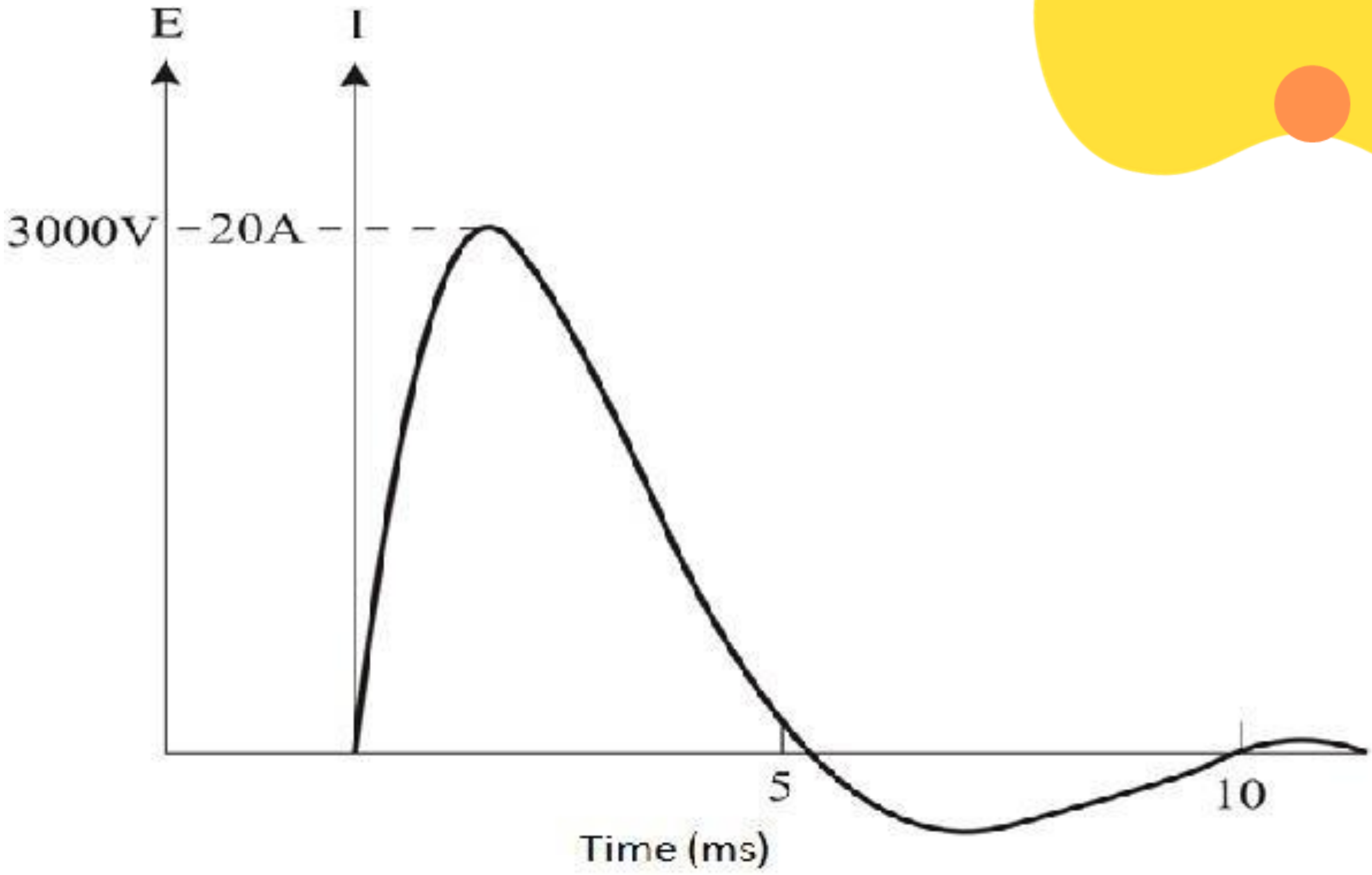
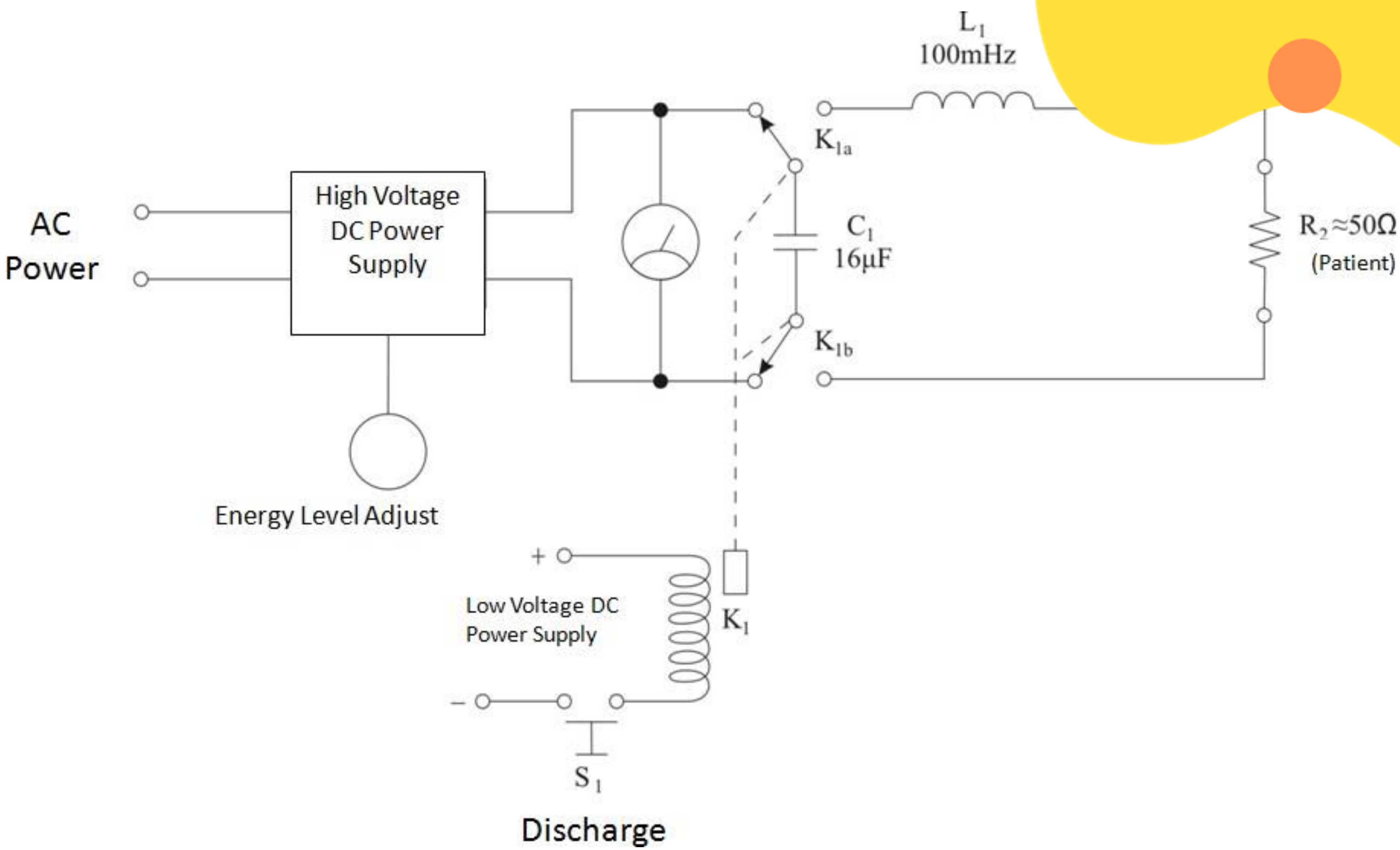
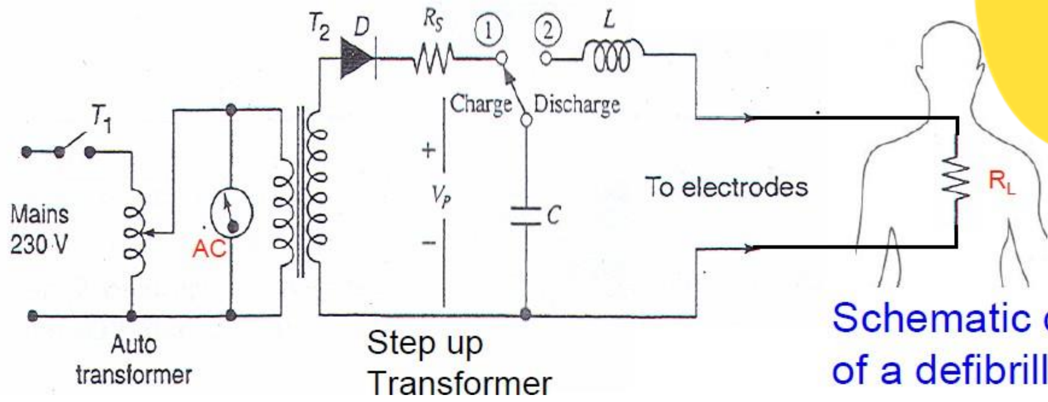


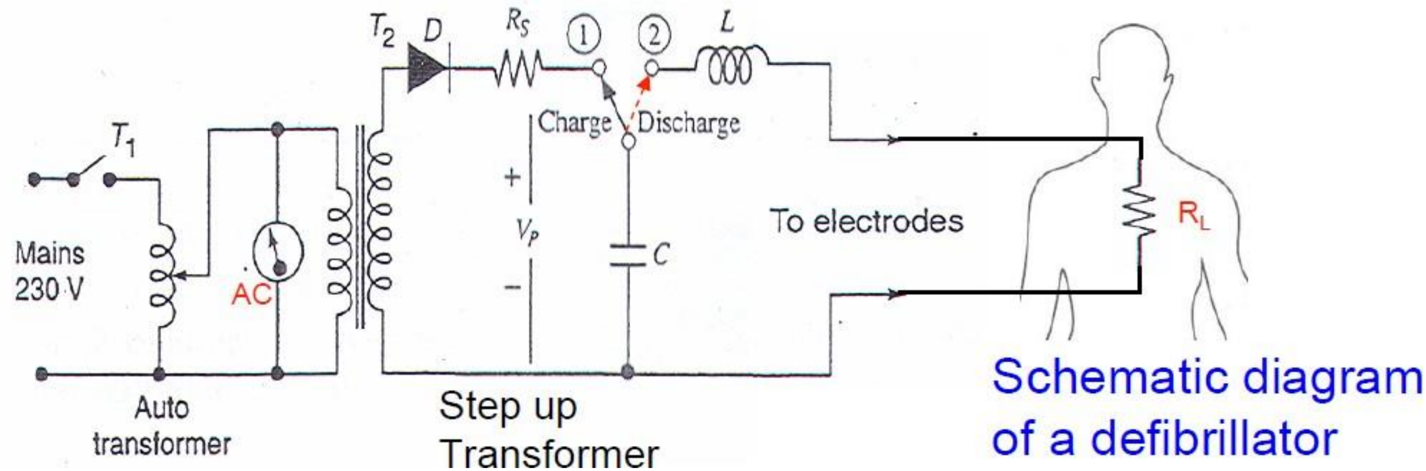
Fig 4.2 Lown waveform



g. 4.3 Simplified Lown Defibrillator Circuit

- Detailed Defibrillator Design





arging current to protect the circuit and determine the
rge on C (T=RC)

- In Lown defibrillator we also have 100mH inductor and patients resistance (R_2). L_1 inductor is causing the 5ms negative p of the Lown waveform.

- How the device works:

1. User adjusts the energy level kob and presses charge button to charge the capacitor.
2. C_1 begins to charge until the the voltage on the capacitor reaches to the potential of the high voltage power supply.

3. User places the electrodes onto the patient chest

button (S_1).

4. K_1 relay seperates capacitor from power supply and connects it to the output circuit.

5. C_1 capacitor discarges its load to the patient through L_1 and R_1. This happens in first 4 -6 ms and the positive high voltage pulse shown in Fig. 4.2. is generated.

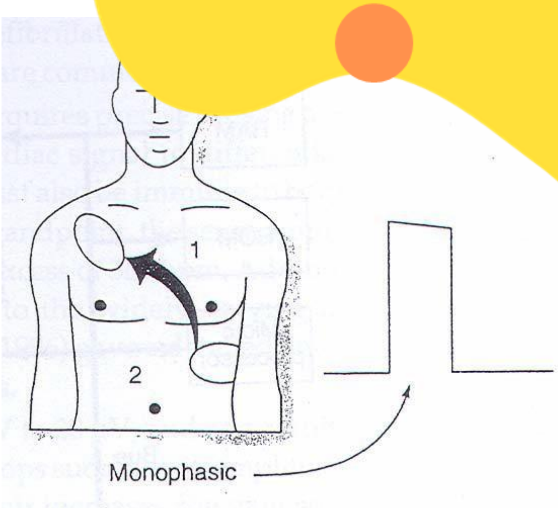
Magnetic fields generated around L_1 during the discharge produce

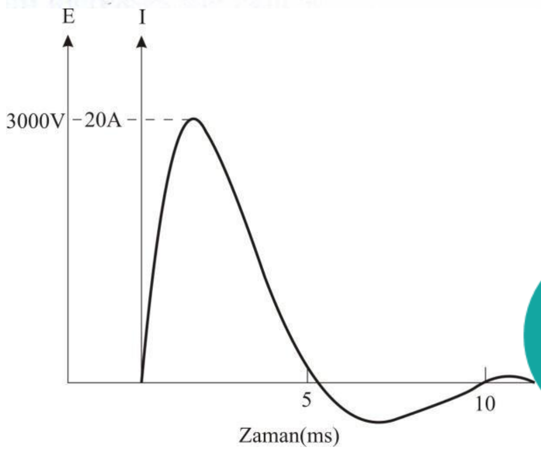
that can be seen in the last 5ms of Fig. 4.2

- Modified Lown waveforms called “Monopulse” (Fig 4.4) are used in portable defibrillators. Design is almost same as in Fig 4.3 but they dont include the L_1 that produces the negative pulse.

Mono-phasic wavefor

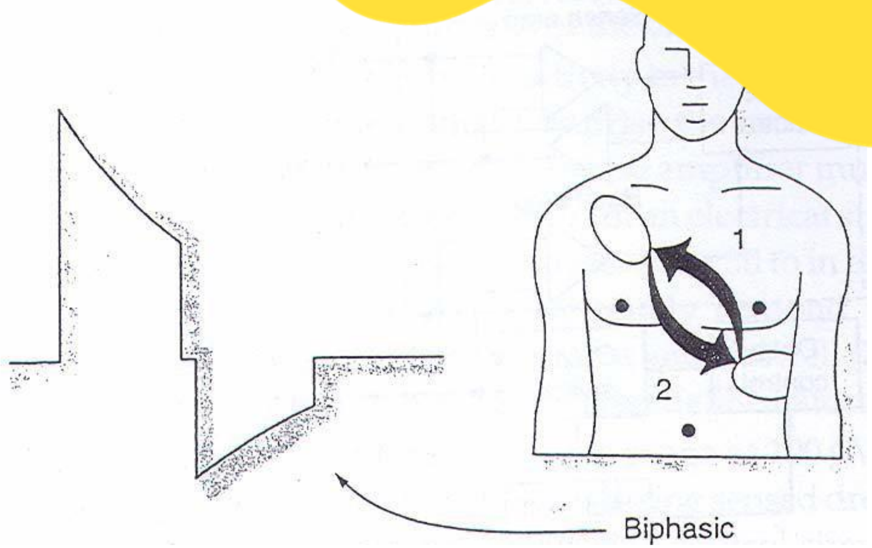
- The delivered energy through the patient's chest is in a single direction
  - ➢ current flows in one direction from one electrode to the other
  - ➢ High level of energy





Bi-phasicwaveform

- The delivered energy through the patient's chest is in two direction.
- deliver current in two directions
- The Bi-phasic waveform reverses the direction of the electrical energy near the midpoint of the waveform
- Low-energy biphasic shocks may be as effective as higher-energy monophasic shocks
- Biphasic waveform defibrillation used in most of the modern defibrillators, implantable cardioverter-defibri… (ICDs) and automated …illators (AEDs).



- Fig.4.3 shows a simplified Lown defibrillator design. The charge that is delivered to the patient is stored in a capacitor and it is supplied by a high voltage power supply. User can adjust the load by changing the energy control knob on the device. This knob changes the maximum load charge (energy) on the capacitor by changing the voltage produced by the high voltage power supply. Capacitors load is controlled by the relay K_1.

- Amount of energy stored on the capacitor is:
- $U=(1/2)CV^2$

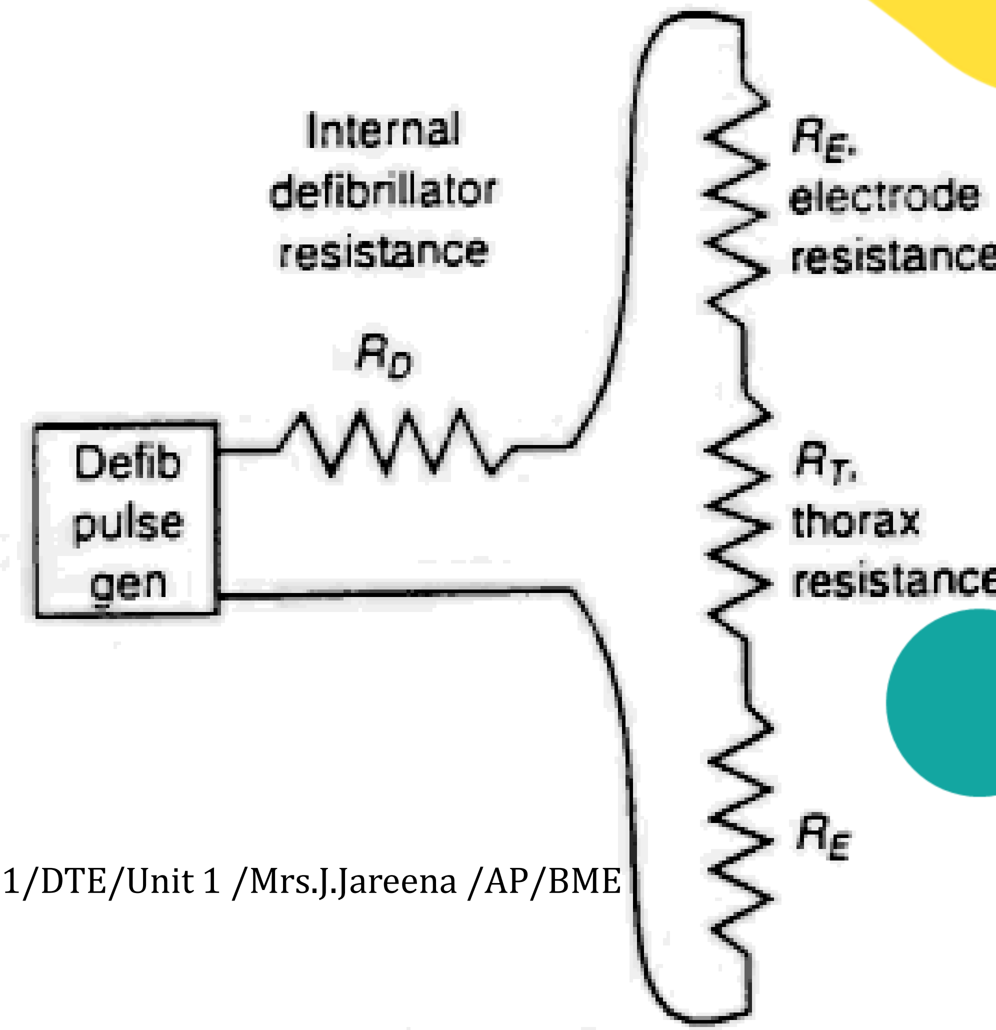
- In this equation;

- U: Energy (joule)
- C: Capacitance of C_1 (Farad)
- V: Voltage on C_1 (Volt)

- Example : Calculate the energy stored in a 16 uF capacitance when the capacitor is charged to 5000 Vdc.

- $U=(1/2)CV^2= 200J$

- To calculate how much of this energy gets to the patient, resistance R_T, consider the equivalent circuit.
  - The four resistors in this circuit are in series.



- Therefore, the current in each of them is the same.
  - And the energy absorbed by any one resistor is proportional to the total available energy, according to the voltage division principle.
    - The formula for the energy absorbed by the thorax, W_T is

$$W_T = \frac{R_T}{R_D + 2R_E + R_T} W_D$$

EXAMPLE

- A defibrillator has an available energy, W_A, of 200 joules (J).
  - If the thorax resistance is 40 ohms (Ω), the electrode—skin resistance of a paddle with sufficient electrode gel is 30 ohms and the internal resistance of the defibrillator is 10 ohms.
    - Calculate the energy delivered to the thorax of the patient.

Solution

- In this case, R_T = 40 ohms, R_E =30 ohms, and R_D = 10 ohms. The equation for the amount energy delivered yields

$$W_T = \frac{R_T}{R_D + 2R_E + R_T} W_D$$

$$W_T = \frac{40}{10 + 2 \times 30 + 40} 200$$

$$W_T = 72.7 \, Joules$$

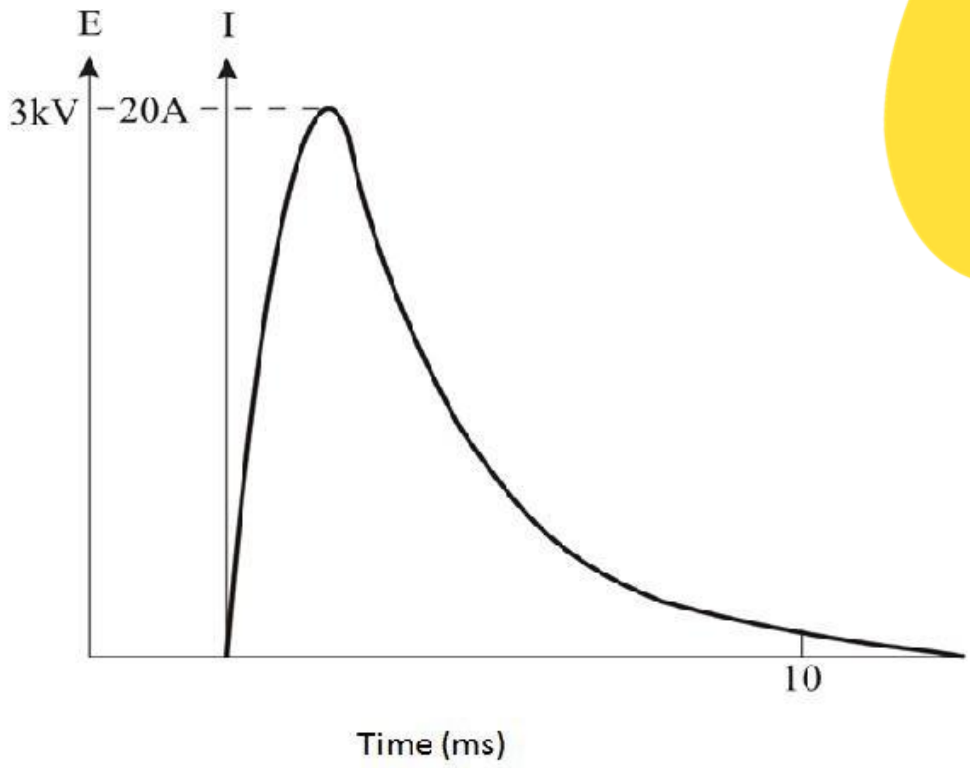


Fig 4.4 Monopulse waveform

- **Monopulse** is a modified lown waveform and commonly found in certain portable defibrillator.
y the same circuit of lown but without inductor L.

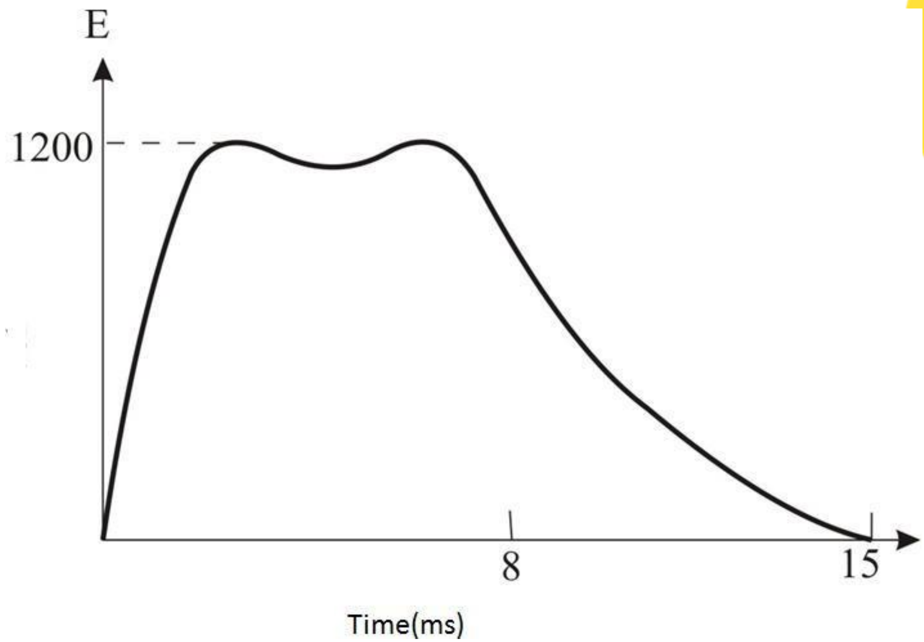


Fig. 4.5 Delayed (variable slope) waveform

- **Tapered** delay wave form , a lower amplitude 1.2 kV and longer duration 15 ms to achive the energy level
- It is created by placing two L–C sections

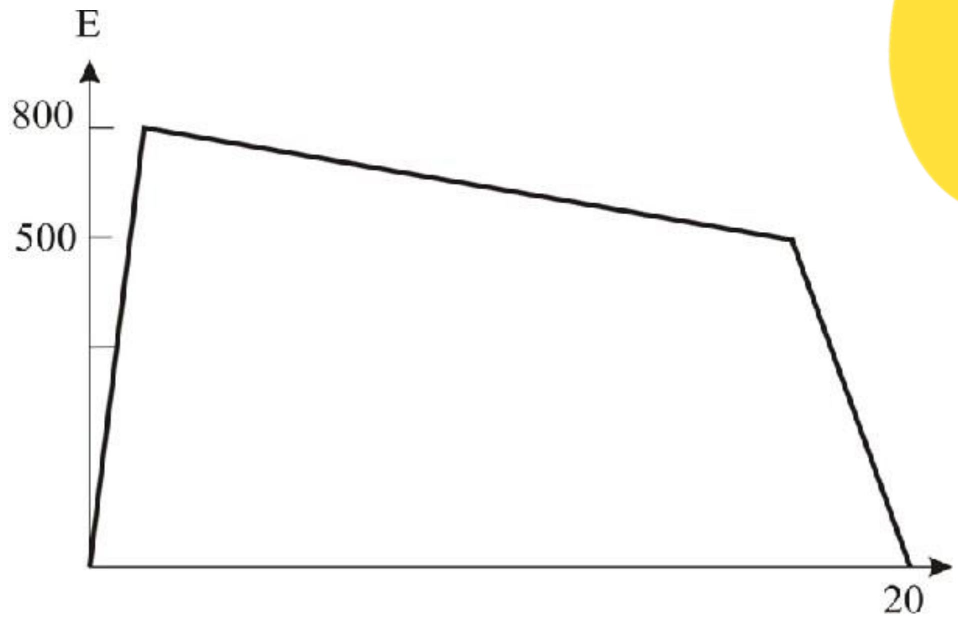


Fig. 4.6 Trapezoidal waveform

- **Trapeziodal** low voltage / long duration (800 V : 500 V & 20 ms)

Defibrillator Electrode

- Before using the defibrillator user must detect the presence of ventricular fibrillation by using an ECG device. Almost all of the modern defibrillator devices include a built in ECG monitor.

Cardioversion

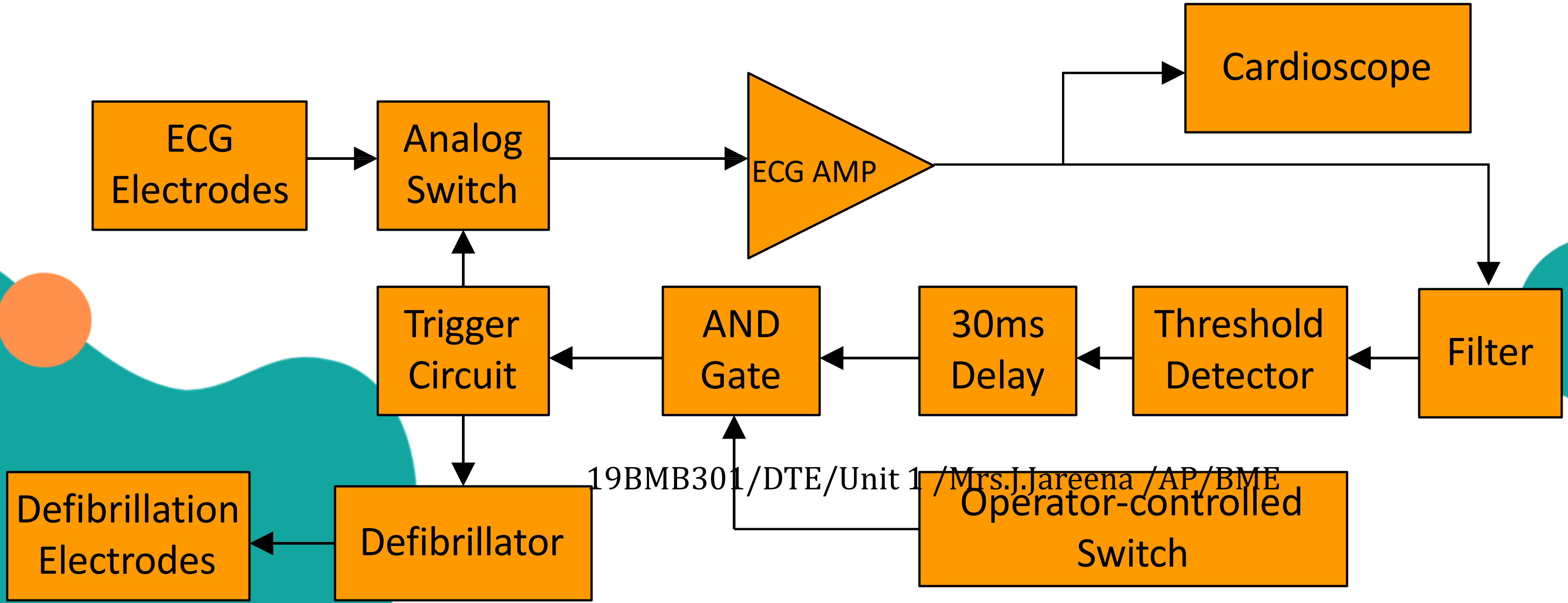
- In some arrhythmia situation (like atrial fibrillation) heart continu to pump blood and this can be observed in ECG by the presence of R wave. These type of arrhythmia can be corrected by delivering shock; but this shock should not be delivered at the moment of ventricular relaxation (moment of T wave in ECG). If it meets the relaxation period the shock can cause a more serious problem of ventri illatio

eds to be applied exactly 30ms later than the R peak.

- It is very hard to do this manually. So an automated circuitry carries out this job. These devices are called Cardioverters.
- By changing a switch user can choose between defibrillation and cardioversion mods. In some devices it is also called as synchronized defibrillation.

Cardioverters

- Special defibrillator constructed to have synchronizing circuitry so that the output occurs immediately following an R wave
  - In patients with atrial arrhythmia, this prevents possible discharge during a T wave, which could cause ventricular fibrillation
- The design is a combination of a cardiac monitor and a defibrillator

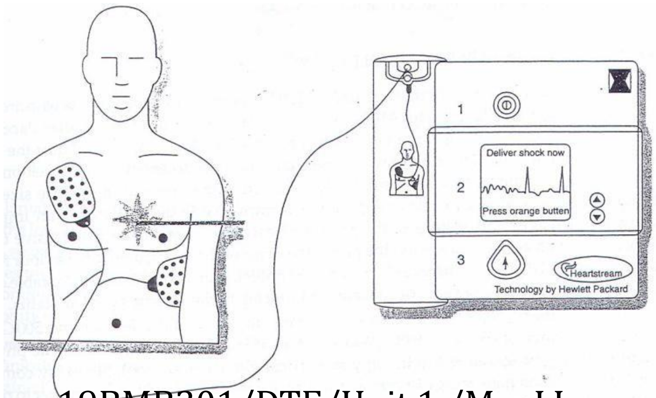


Types of Defibrillators

- **Manual Defibrillator;**
- Manual defibrillator is a normal DC defibrillator where:
- The clinician decide what charge (voltage) to use, based on their prior knowledge and experience, and will deliver the shock through paddles or pads on the patient's chest.
- They require detailed medical knowledge
- These unit are generally only found in hospitals and on ambulances.

- **Automatic External Defibrillators (AED's)**
- A unit based on computer technology and designed to analyze the heart rhythm itself, and then advise whether a shock is required.
- It is designed to be used by lay persons, who require little training.
- It is usually limited in their interventions to delivering high joule shocks for *VF and VT rhythms*
- The automatic units also take time (generally 10-20 seconds) to diagnose the rhythm, where a professional could diagnose and treat the conditi… quicker with a manual unit
- …ound in public places.

- AED's require self-adhesive electrodes instead of hand-held paddles for the two following reasons:
- The ECG signal acquired from self-adhesive electrodes usually contains less noise and has higher quality ⇒allows faster and more accurate analysis of the ECG ⇒better shock decisions
- "Hands off" defibrillation is a safer procedure for the operator, especially if the operator has little or no training



- ***Implantable Defibrillators (AID):***
- Recommended for patient who are at high risk for ventricular fibrillation. It constantly monitors the patient's heart rhythm, and automatically administers shocks for various life threatening arrhythmias, according to the device's programming

- ***Implantable Cardioverter Defibrillators* (ICDs):** It combines both defibrillator and cardioverter devices in one implantable unit. Used in patients who have high risk of sudden cardiac death due to ventricular fibrillation and ventricular tachycardia.

- constantly monitors patients heart rate and rhythm. When it detects a very fast, abnormal heart rhythm, it delivers energy to the heart muscle. This causes the heart to beat in a normal rhythm again.
- Similar to pacemakers, these devices typically include electrode wire(s) that pass through a vein to the right chambers of the heart, usually lodging in the apex of the right ventricle. The difference is that pacemakers are more often temporary and are generally designed to correct bradycardia, while ICDs are often permanent safeguards against sudden arrhythmias.
- Mainly used for: **Anti-tachycardia Pacing (ATP), Cardioversion, Defibrillation and Bradycardia pacing (if have pacing ability)**