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Biomedical Signals Recorders and Monitors

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A Basic Biomedical Recording System

A recorder provides a lasting visual record of an electrical signal. The basic electronic recording system consists of three key components:

1. Electrodes/Transducer: Electrodes detect bioelectric potentials, and transducers convert physiological signals into electrical outputs.
2. Signal Conditioner: This adjusts the output from the electrodes or transducer into an electrical value that can drive the recording system.
3. Writing System: It generates a visible graphical representation of the measured physiological variable.

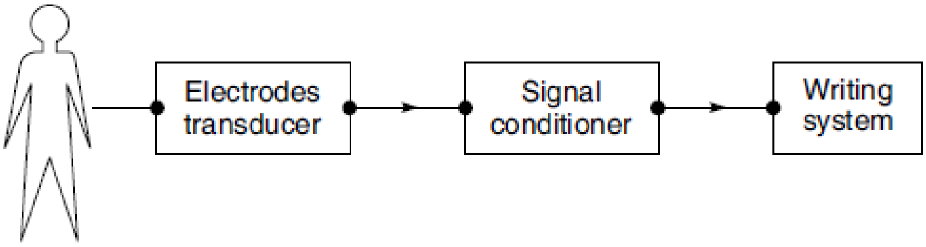

Figure 1 A Basic Electronic Recording System

In medical recording devices, the signal conditioner, which includes a preamplifier and main amplifier, ensures accurate signal reproduction by adjusting parameters like input impedance, gain, and frequency response. It standardizes transducer outputs to a consistent level, typically one volt, making the signal compatible with the recording system. This standardization allows various physical or bioelectric events to be recorded by switching the signal conditions. Common writing systems include inkjet, galvanometer-type pen, and potentiometric recorders, which produce visual representations of the signals.

Electrode-Tissue Interface:

Surface electrodes are widely used in patient monitoring for recording ECG, EEG, and respiratory activity through impedance pneumography. To reduce movement artifacts and ensure a strong connection with low contact impedance, an electrolyte or electrode paste is applied between the electrode and the skin. The performance of a surface electrode, which is a metal electrode attached to the body via an electrolyte, depends on three key factors: the conditions at the metal-electrolyte interface, the electrolyte-skin interface, and the quality of the electrolyte.

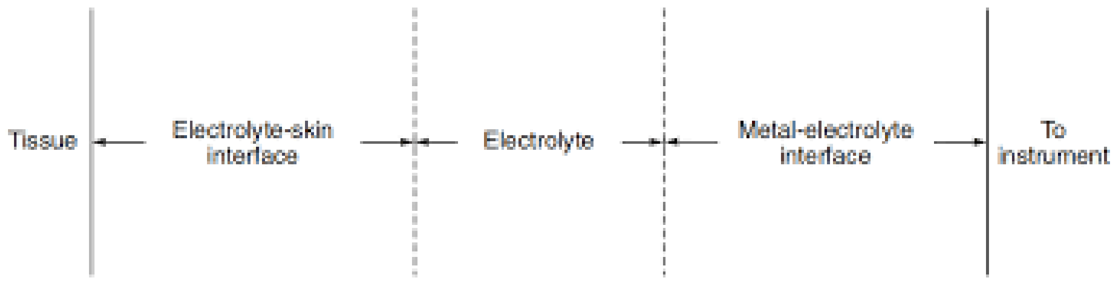

Figure 2 (a) Electrode-tissue interface for surface electrodes used with electrode jelly.

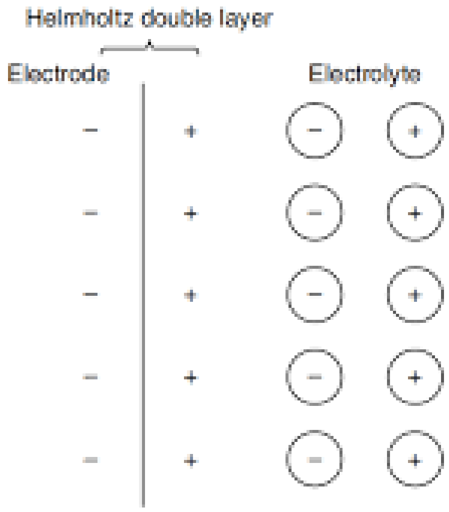

Figure 2 (b) The electrode tissue interface circuit involves transfer of electrons from the metal phase to an ionic carrier in the electrolyte, a charge double layer (capacitance) forms at the interface.

<u>Electrolyte-Skin Interface:</u>

The electrolyte-skin interface can be approximated by assuming the skin functions as a diaphragm positioned between two solutions (the electrolyte and body fluids) with different ion concentrations, leading to potential differences. A simple equivalent model can be represented by a voltage source in series with a parallel combination of capacitance and resistance. The capacitance reflects the charge formed at the phase boundary, while the resistance is influenced by ion migration along the phase boundaries and within the diaphragm. This suggests the potential presence of non-physiological voltages, known as contact potentials.

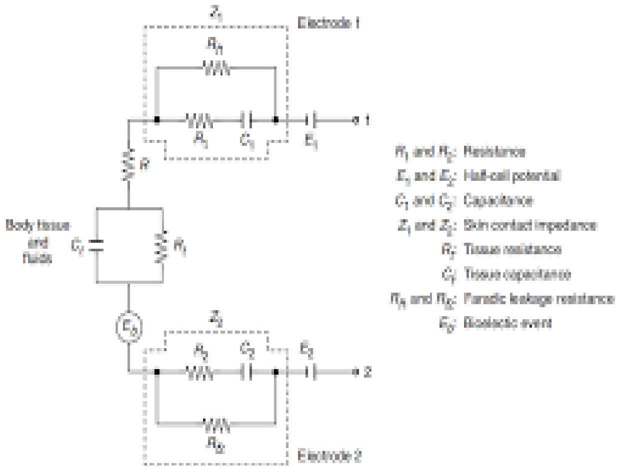

Figure 3: Equivalent circuit for a pair of electrodes (1, 2) on a subject represented by R, R t, Ct. Embedded in the subject is a bioelectric generator Eb (after Tacker & Geddes, 1996)

Types of Bioelectrodes

Introduction

Bioelectric events are detected using electrodes, which capture potentials at various points on the body and transmit them to amplifiers for further processing. Bioelectrodes are classified into two types:

- **Surface electrodes:** Collect potentials from the surface of the tissue.
- **Deep-seated electrodes:** Inserted into live tissue or cells.

When surface electrodes are used for measurements outside the body, it’s called **in vitro** measurement, while using needle electrodes inside the tissue is termed **in vivo** measurement.

Key Properties of Bioelectrodes

Bioelectrodes should possess the following properties:
•They should be good conductors
•They should have low impedance
•They should not polarize when a current flows through them
•They should establish a good contact with the body and not cause motion
•Potentials generated at the metal electrolyte (jelly) surface should be low.
•They should not cause itching, swelling or discomfort to the patient for example the metal should not be toxic
•They should be mechanically rugged
•They should be chemically inert
•They should be easy clean
Figure 4 shows how the electrodes make contact with the skin surface.

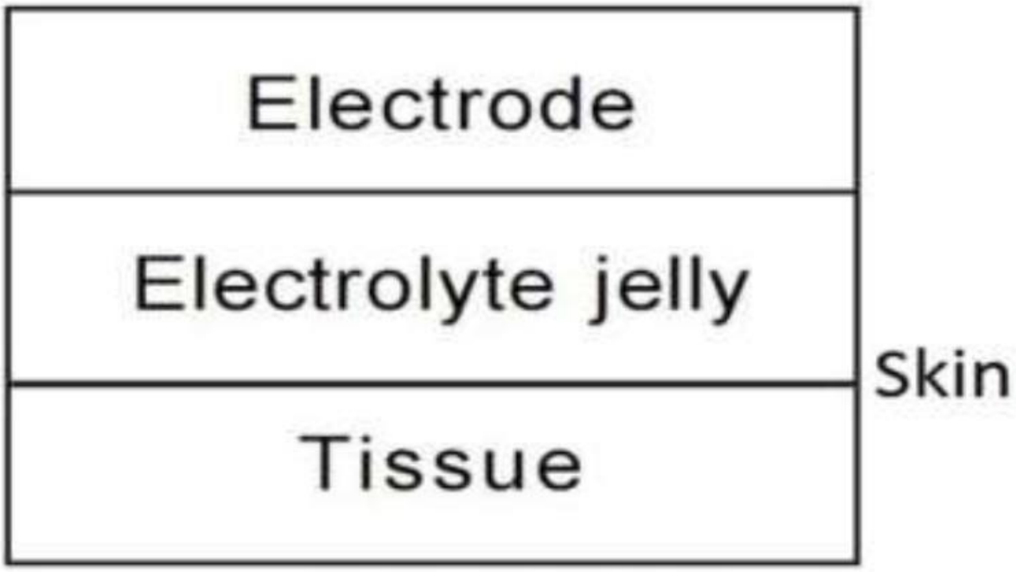

Figure 4 Electrolyte-skin interface

The Skin Contact Impedance

The outer layer of the skin has large impedance which is much greater than the electrical impedance of body tissue beneath the skin. The outer layer skin is responsible for the bulk of the skin contact impedance and therefore, a careful skin preparation is essential in order to obtain best results.

Types of Electrodes used in Biomedical Measurements

The three basic types of biopotential electrodes used in biomedical measurements are:

1. Microelectrodes
2. Skin surface electrodes
3. Needle electrodes

Microelectrodes

Microelectrodes are designed to measure bioelectric potentials near or within cells. To avoid cell damage, they are much smaller than the cell, typically having a tip size of about 5 microns, as most cells are under 500 microns. The tip must be strong enough to penetrate the cell without causing harm. Microelectrodes come in two types:

1. **Metal**
2. **Micropipette**

METAL MICROELECTRODES

Metal microelectrodes are fine metal needles with insulated coatings, except at the tip. They measure biopotentials at the metal-electrolyte interface, where the electrode potential reflects ion exchange between the metal and the body's electrolyte. These microelectrodes come in two types:

1. **Metal microelectrodes**
2. **Micropipette microelectrodes**

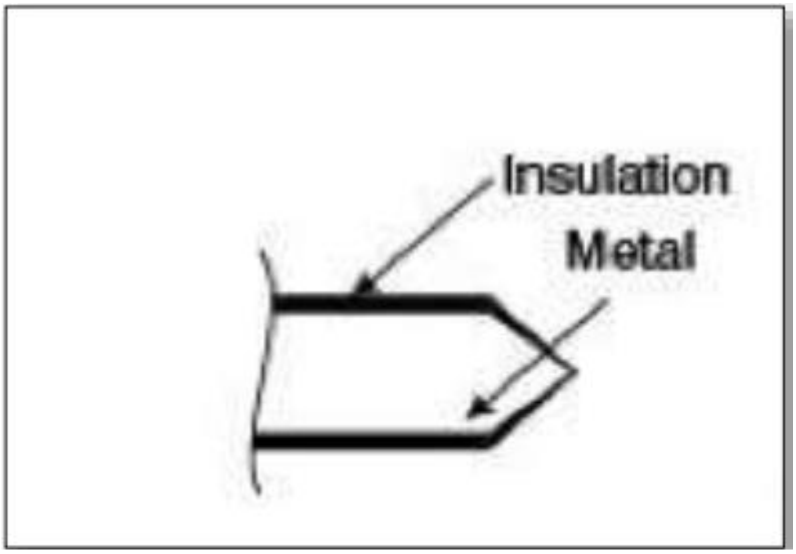

Figure 5 Metal microelectrode

Body Surface Electrodes

Body surface electrodes are designed to measure ECG, EEG, and EMG potentials from the skin with minimal trauma. They come in various forms and sizes. Larger electrodes are used for ECG measurements, where specific placement is less critical, while smaller electrodes are used for EEG and EMG, where precise localization is important. Common types like metal plate and suction cup electrodes can slip or move, causing incorrect measurements. To prevent this, floating electrodes are used, which avoid direct contact with the skin by using an electrolyte paste or jelly, reducing movement artifacts.

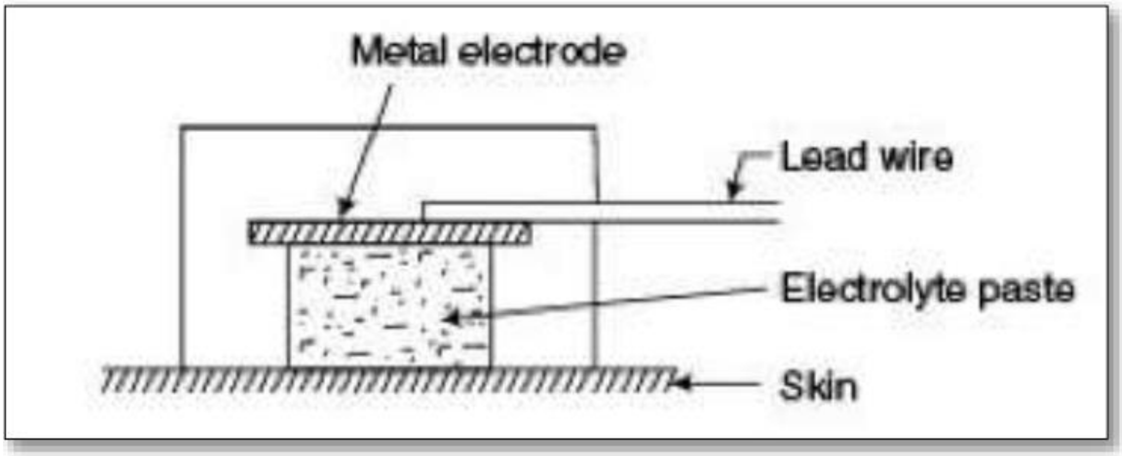

Figure 7 Floating type body surface electrodes

TYPES OF SURFACE ELECTRODES

Examples of surface electrodes include:

1. Limb electrode
2. Disposal electrode
3. Pre-gelled electrode
4. Circular electrode.

More details on Surface electrodes are shown in the figure below, From above, Figure 8 (a), shows a rectangular electrode held together in position by elastic rubber straps. Figure (b), shows a disposal electrode with adhesive to hold the electrode in position. Figure (c) exhibits disposable pre-jelled electrodes. Figure (d) shows a circular electrode, with a rubber bulb which creates a partial vacuum so that the electrode is held in a position and no adhesive is used.

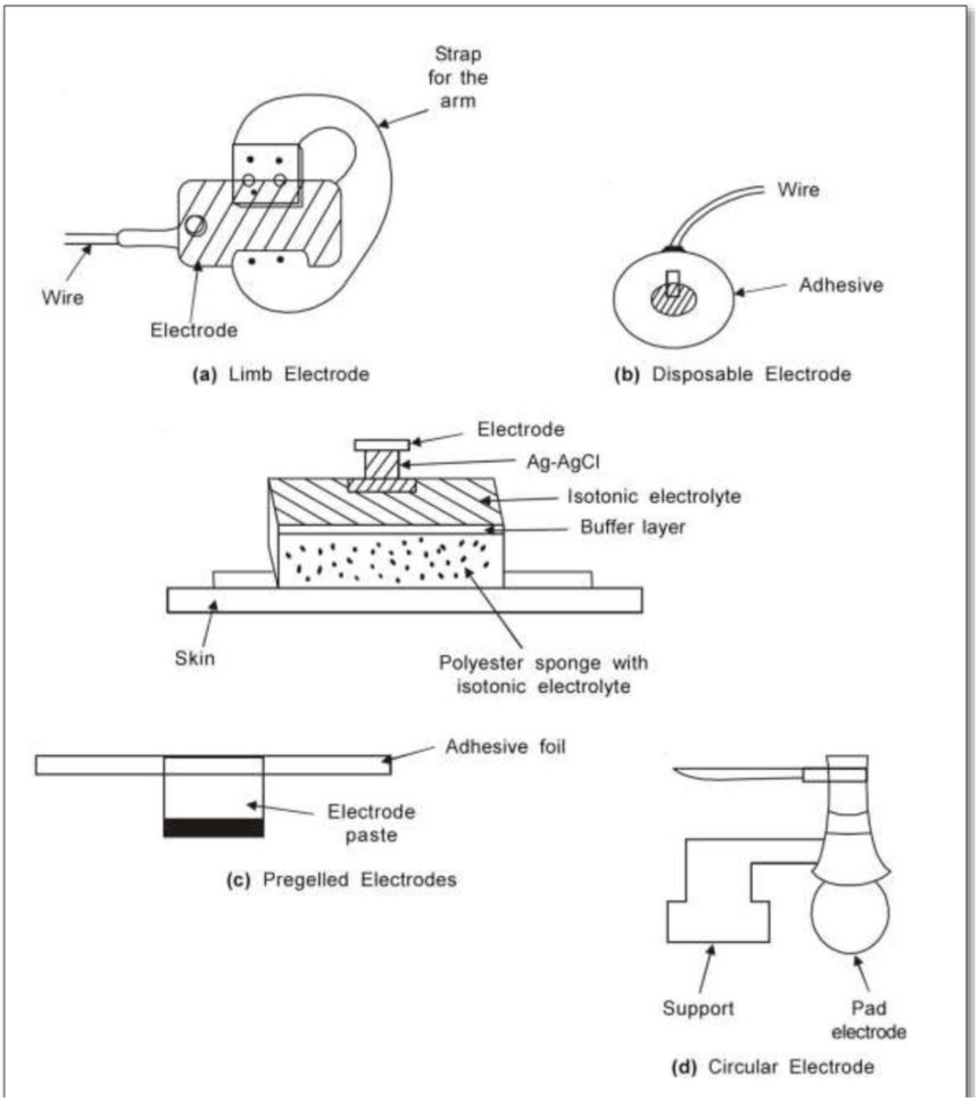

Figure 8 Types of Surface Electrodes used in Biomedical Instrumentation.

Needle Electrodes

They are generally made of stainless steel. These electrodes are designed to penetrate the skin surface of the body to some depth to record EEG potentials of a region of the brain

or EMG potentials of a muscle. These electrodes have to be sharp and small like subdermal needles which help them to easily penetrate the scalp for measuring the EEG potentials. They

are required to penetrate up to some surface at certain depth of the skin which is parallel to the surface of the brain or muscle.

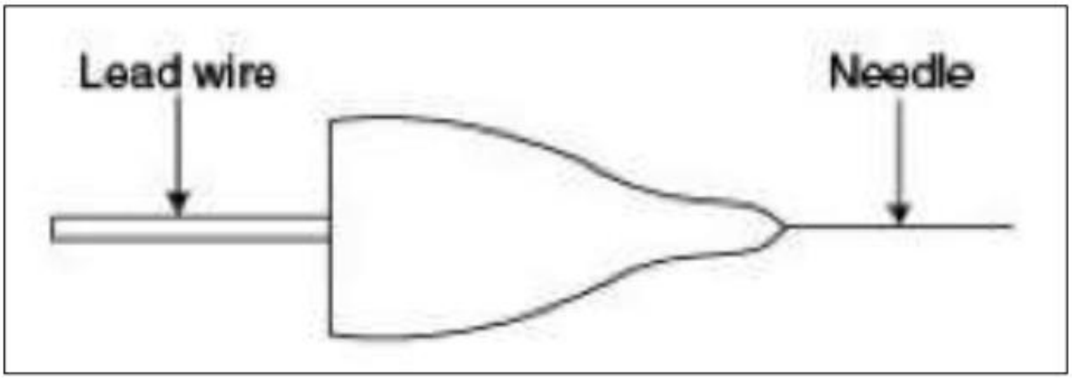

Figure 9 Needle electrode for EEG