OMD551 Basics of Biomedical Instrumentation

ELECTRODE

- Electrodes are devices that convert ionic potentials into electronic potentials
- It acquires signals like ECG, EEG, EMG.
- An electrode potential is developed across the interface proportional to the exchange of ions between the metal and the electrolytes of the body
- Measurement of bioelectric potentials requires two electrodes
- The voltage measured is the difference between the instantaneous potentials of the two electrodes

Body Surface Electrodes

Used to sense the potential from heart, brain and nerves

1. Immersion Electrodes
2. Plate Electrode or Metal Plate Electrodes
3. Metal Disk Electrode
4. Disposable Electrodes
5. Suction cup Electrodes
6. Floating Electrodes
7. Flexible Electrodes
8. Special Electrodes

Needle Electrodes - EEG needle electrode

Micro Electrodes

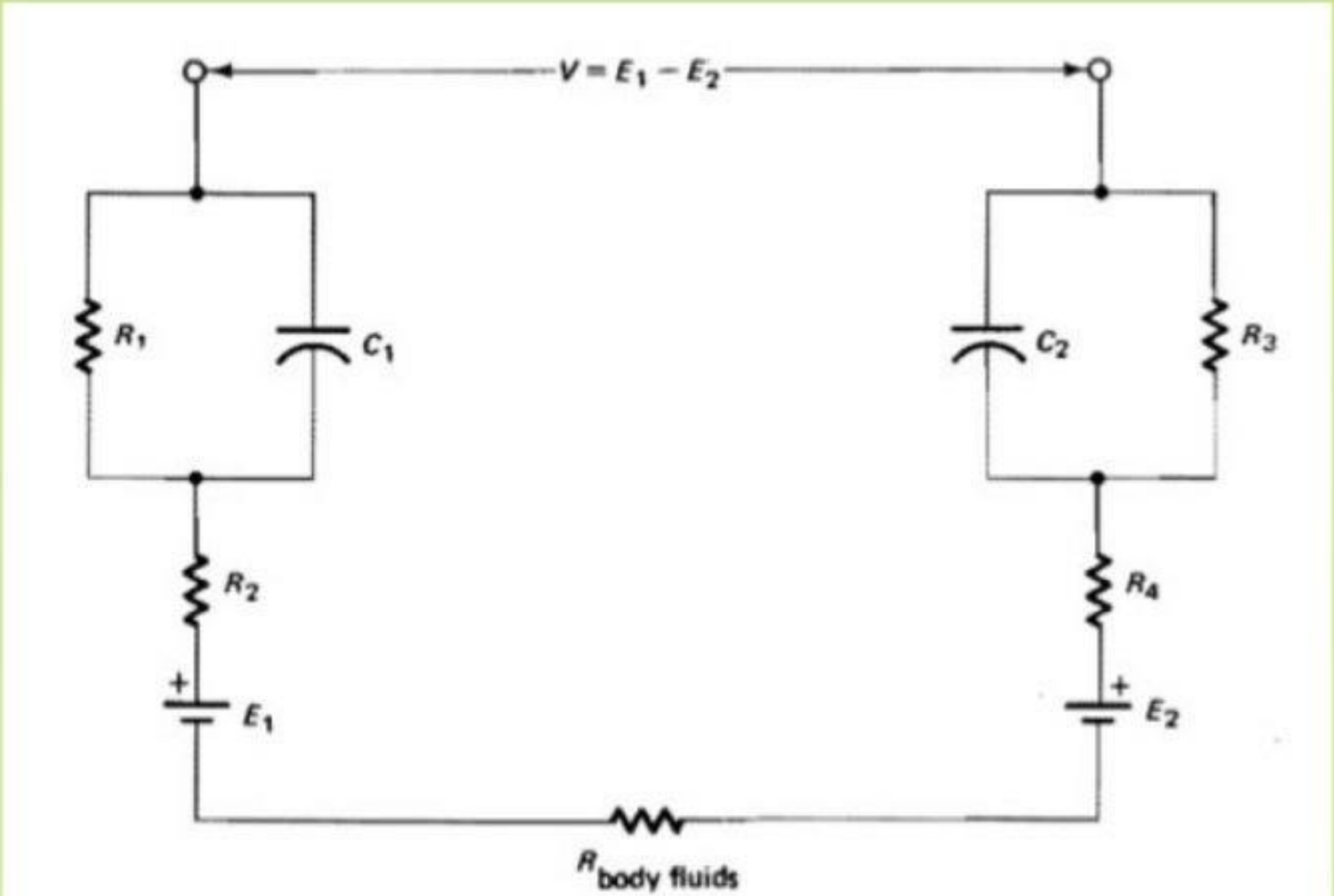
- Measures potential within a cell
- Diameter- 0.05 µm **-10** µm
- No damage to human cell

Types

1.Metal micro electrode

2.Micropipette electrode

EQUIVALENT CIRCUIT OF BIOPOTENTIAL ELECTRODE INTERFACE



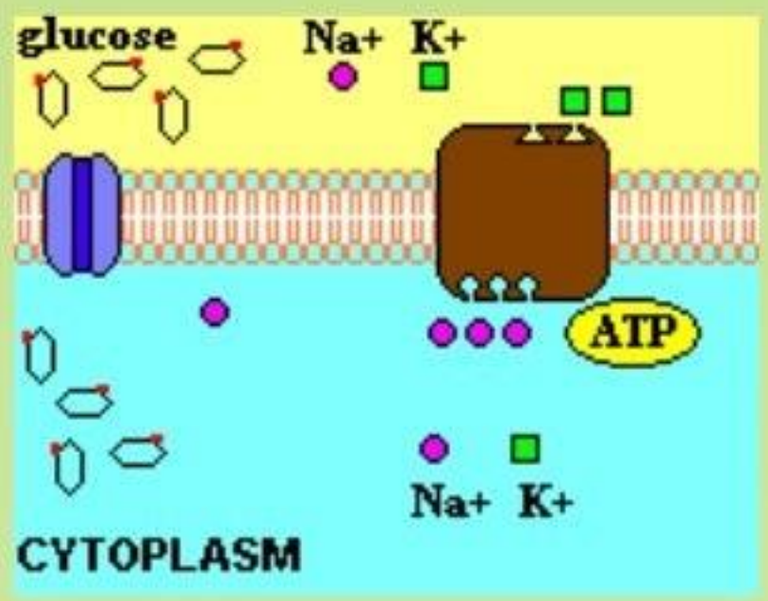
Measurement of biopotentials with two electrodes—equivalent

- The voltage measured is the difference between the potentials of 2 electrodes.
- The dc voltage due to the difference in electrode potential is called as electrode offset voltage.
- 2 electrodes of same material may also produce small electrode offset voltage.
- Chemical activity takes place within an electrode can cause voltage fluctuations to appear without any physiological input. Such variations may appear as noise on bioelectric signal.
- This noise may be reduced by proper choice of materials or by coating the electrodes to improve stability.
- Ag-AgCl is very stable.

Ag-AgCl electrode

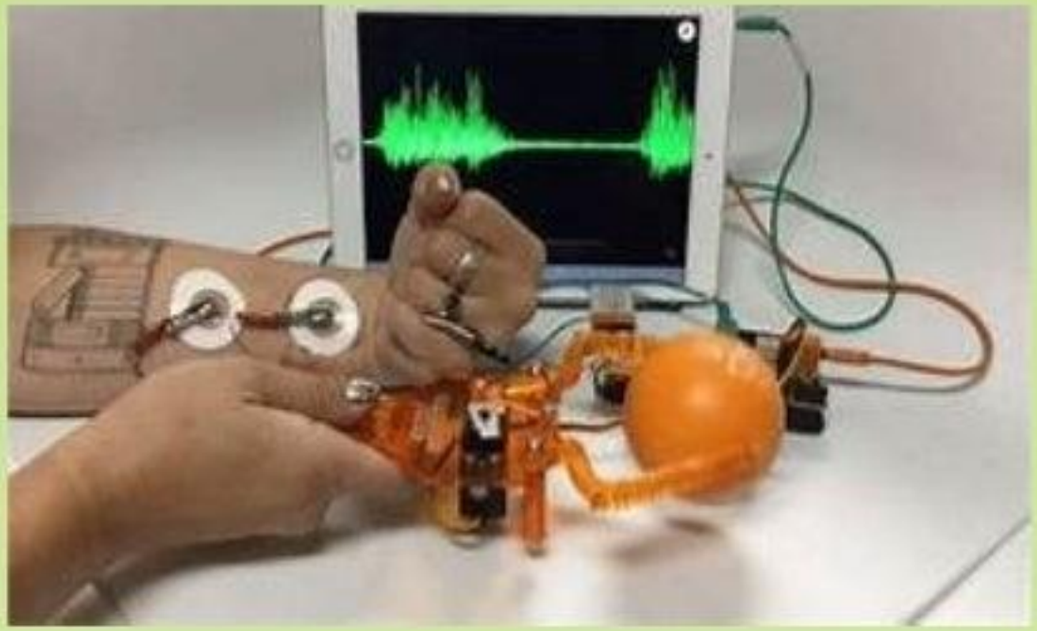
- Ag-AgCl electrode is prepared by coating a pure silver with silver chloride.
- This coating is done by placing silver into a bromide free sodium chloride solution.
- A second piece of silver is also placed in the solution and the two are connected to a voltage source.
- Surface electrodes have impedances of 2 to 10 kilo ohm.
- Whereas small needle and micro electrodes have much higher impedances.

- Electric events inside the human body cause potential differences on the skin.
- Surface electrodes can be used to measure these voltages. A surface electrode is in fact an electrochemical transducer.
- It converts the potential differences due to ion flows inside the human body into a measurable voltage.
- The measurement of bioelectric events is exposed to various sources of noise.
- The reactions that take place at the electrode make the electrode itself a source of noise.



The electrode-skin interface

- In medical science the recording of potential differences from the human body is an important source of information.
- Surface electrodes can be used for measuring bioelectric activities of the heart, brain or muscles (ECG, EEG or EMG).
- In the human body the current flow is established through ion movement.
- At the electrode electrolyte interface ions and electrons are arranged in a specific way. This is called the electrical double layer.



Nernst equation

- The potential difference between two regions in a liquid with different ion concentration can be calculated with the Nernst equation.

$$E = -\frac{RT}{nF}\ln\left(\frac{C_1}{C_2}\right)$$

where

E = electrode potential
F = Faraday constant
T = absolute temperature
n = valence of ion involved
C_1 = concentration of ions in the solution
C_2 = concentration of ions at the electrode surface

NEED OF MEDICAL RECORDING

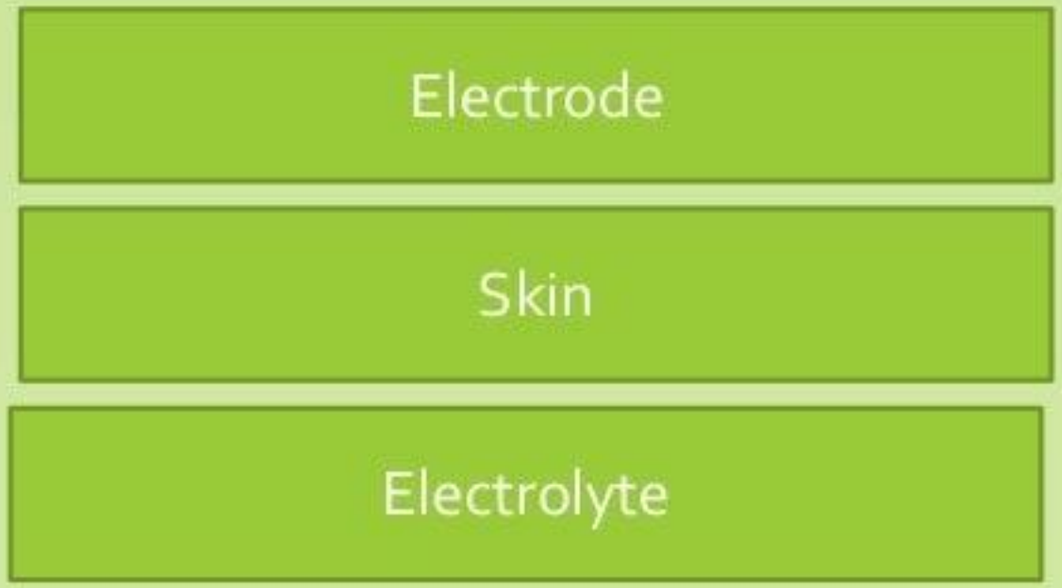
- Better clinical decision making
- Proper treatment
- Save patient

Noise in biopotential recording

- As surface biopotential recording involves the measurement of extremely small potential differences, noise is likely to play an important role.
- The output voltage of an amplifier used to measure bioelectric events is not always an accurate representation of the event under examination.
- It is composed of the desired voltage, and a number of unwanted voltages. The desired voltage is called the signal. All unwanted voltages are referred to as noise.

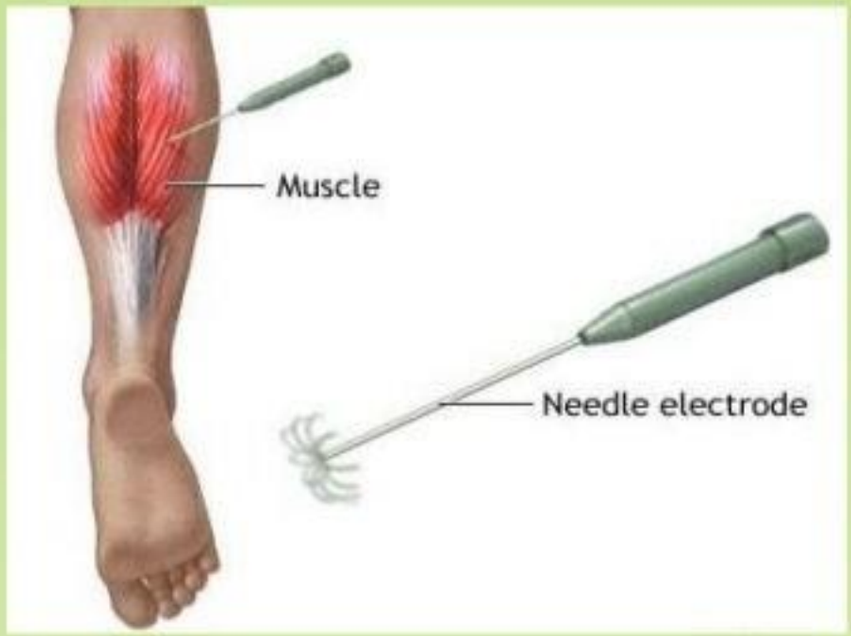
Electrode-electrolyte noise

- The stability of the potential of an electrode depends on the used material and electrode preparation.
- The material that is mostly used for low-noise recording of biopotentials is silver-silver chloride on as potential is relatively stable.



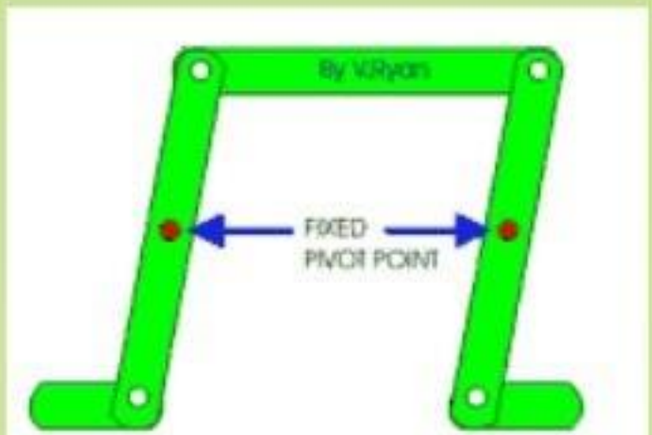
Noise at the electrolyte-skin interface

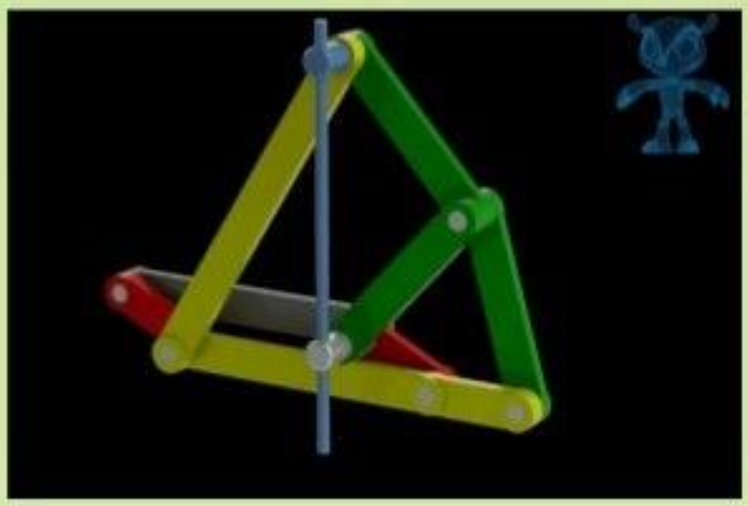
- Measurement of only the noise signal produced by the skin, is a difficult task, as EMG signals and other noise sources will always contaminate the recording.
- Increasing the diameter reduces the excess noise



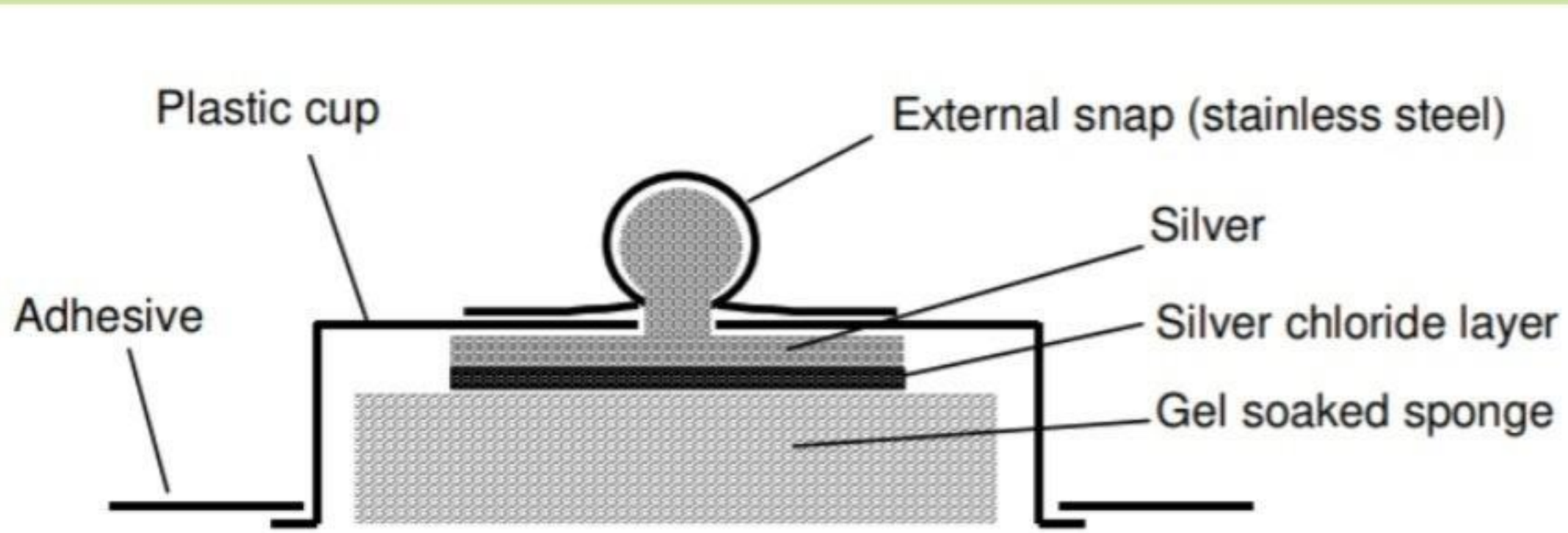
Motion artifact

- Movement can cause changes in the potentials that are created when an electrode is applied to the skin.
- Normally, when the patient is relaxed, and high quality electrodes are used, the recording is not distorted by motion artifact.
- The skin-electrolyte interface can cause artifacts of 400-600 µV when the electrode is moved parallel to the skin surface.
- When the electrode is moved perpendicular to the skin the potential changes can be up to 900 µV.





Cross section of electrode – active surface is recessed in plastic cup to reduce motion artifact



Cable movement

- Cable movement causes artifact is in the strong magnetic field of a MRI-scanner.

Avoided by:

- Amplifying the signal before it enters the cable can also reduce all forms of artifact produced by the wires.
- Various electrodes with amplifier circuits attached to reduce noise

Thermal noise

- Every resistor will produce a certain amount of noise.
- The random movement of charged particles causes thermal noise, and it has a root mean square value of

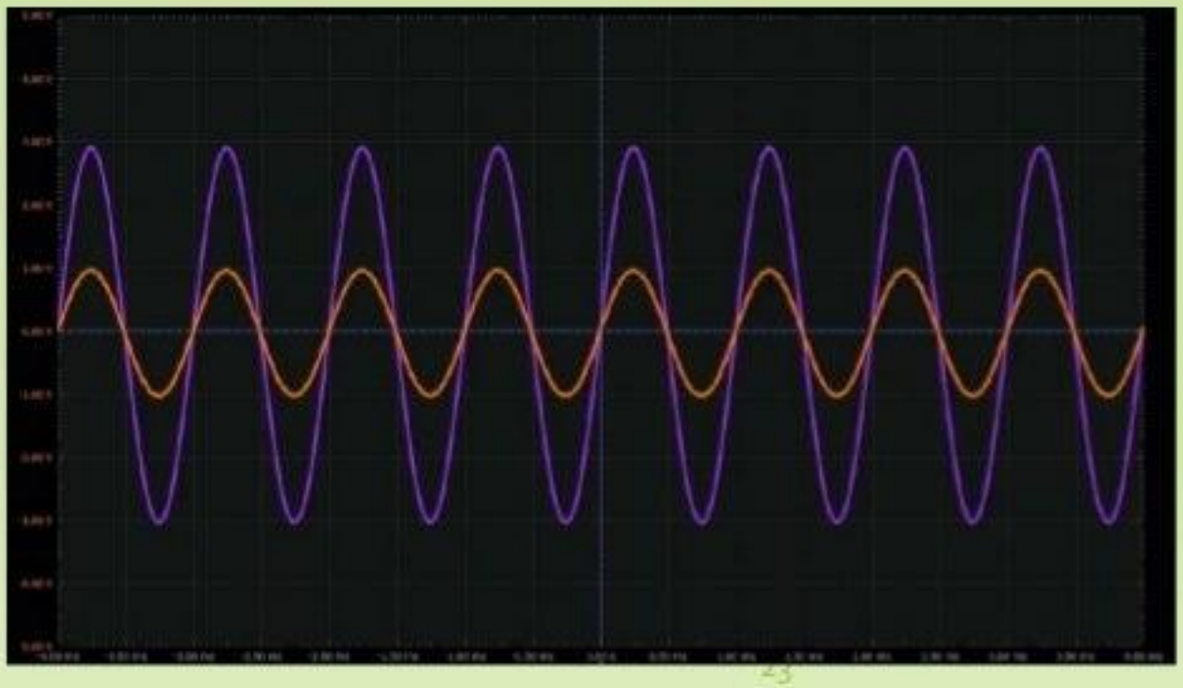
$$V_{th} = \sqrt{4kTBR}$$

where

k is Boltzman's constant ($1.38.10^{-23}$ J/K)
T is the temperature in Kelvin
B is the bandwidth of the voltage measuring device in Hertz
R is the resistance in Ohms

Amplification

- Signal amplification performs two important functions: increases the resolution of the input signal, and increases its signal-to-noise ratio.
- For example, the output of an electronic temperature sensor, which is probably in the millivolts range is probably too low for an analog to digital converter (ADC) to process directly. In this case it is necessary to bring the voltage level up to that required by the ADC.



Amplifier noise

- The noise introduced by the amplifier can be modeled as two uncorrelated noise sources, Vn and In, Ze is the electrode-electrolyte impedance.

- As the noise sources are independent, the total amount of noise from the amplifier is given by

$$V_a^2 = V_n^2 + (Z_e I_n)^2$$

Other noise sources

- Synthetic clothing causes noise
- Radio-frequency interference caused by electrosurgical units.

Avoided by:

- Shielding can cure this problem
- Adequate distance between these sources of interference and the recording equipment.

Thank You