Biopotential Electrodes

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Lecture - Outline

- Bioelectric measurement
  - Biopotential Measurement
  - Electrical Excitation
- Polarization and impedance
  - Implications for measurement
  - Frequency response
- Geometry considerations
  - Frequency response

Biopotentials

- Electrical potentials in excitable tissue
    - cardiac potentials – ECG
    - Brain potentials – EEG
    - Muscle and nerve – EMG, ENG
- Change in position and magnitude of charge separation (“dipole”)
- Generator potentials, action potentials, etc.

Measurement of biopotentials

- Measure the electrical field or potential at a point
- Conductive electrode placed in the tissue
- Record time-varying magnitude of potential

- Critical factors
  - Location of source
  - Orientation of nerve cells/muscle fibres along which dipole moves
  - Location and orientation of electrodes

Electrode Configuration for Biopotential Measurement

- Unipolar measurement
  - Measure potential at single point
  - Ground or Reference is an electrically inactive region
- Biopolar measurement
  - Differential measurement between two points
  - Ground or Reference at an inactive region
  - Differential Mode Measurement is signal
  - Common mode is noise

Measurement model

- Biological source – electrical source and source impedance
- Electrode-tissue interface
    - polarization potential
    - Electrode-tissue impedance
- Biopotential amplifier
    - Input impedance
        - Impedance between Differential inputs
        - Impedance between input and ground

Measuring Biopotentials

- Measured potential
  - Biological source
  - Half cell potential
  - Ion mobility across gradient
  - Electrode impedance Ohmic drop
- $V_m(t)=V_b(t)+V_h+V_c(t)+V_R(t)$

Biopotential electrodes

- Electrodes have half-cell potential, ohmic potential drop, polarization potential

- Half-cell potentials w.r.t. hydrogen electrode

$$H_2 \rightarrow 2H^+ + 2e \quad \Rightarrow 0\,V$$
$$Al \rightarrow Al^{+++} + 3e \quad \Rightarrow -1.7\,V$$
$$Cu \rightarrow Cu^{++} + 2e \quad \Rightarrow +0.34\,V$$
$$Ag + Cl \rightarrow AgCl + e \quad \Rightarrow 0.233\,V$$

- Separation of ionic solutions
  - Nernst potential

$$V_C = \frac{RT}{nF} \log_e \left(\frac{C_1}{C_{ref}} \right)$$

Electrochemical Cell Potentials

Half-cell potentials	
$Al \rightarrow Al^{3+} + 3e^-$	-1.709
$Ag \rightarrow Ag^{+} + e^-$	+0.799
$Fe \rightarrow Fe^{2+} + 2e^-$	-0.409
$Cu \rightarrow Cu^{2+} + 2e^-$	+0.340
$Zn \rightarrow Zn^{+} + 2e$	-0.763
$Ag + Cl^- \rightarrow AgCl + e^-$	+0.223

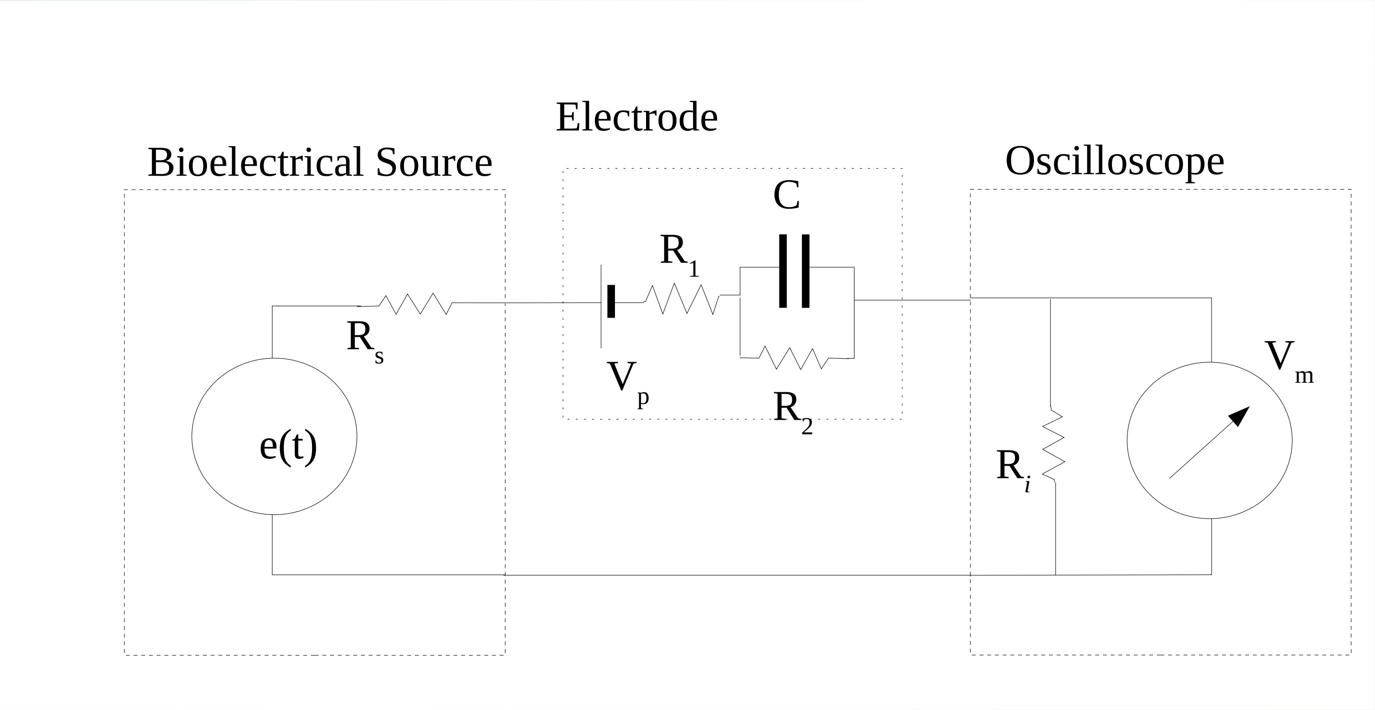
Artifacts in Biopotential recording

- Change in activation – movement
- Polarization potentials

- Ag/AgCl Electrodes
- Movement artifacts

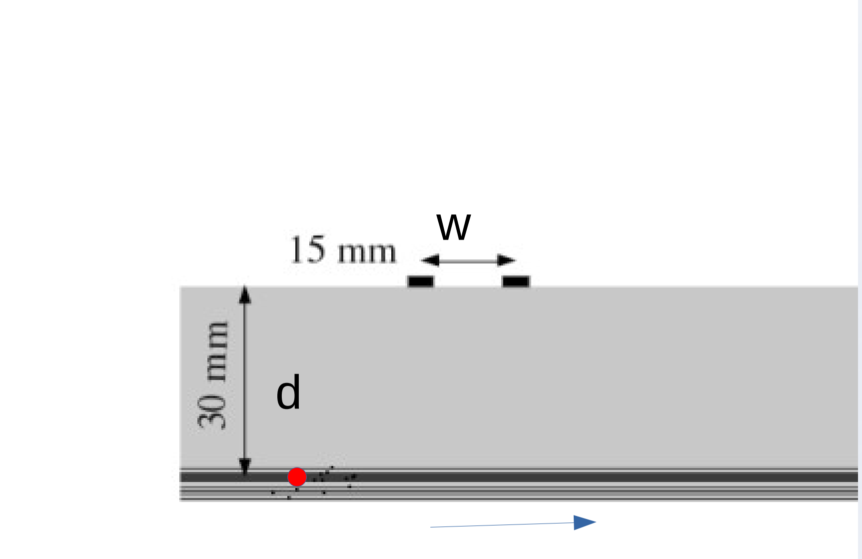
- Electrodes as filters

Measurement model



Electrode geometry and filtering – Bipolar electrodes

- Size and separation of electrodes



$$e_S(t) = \frac{I_o}{4\pi}\left\{\frac{1}{\sqrt{(z-ut-w/2)^2+d^2}} - \frac{1}{\sqrt{(z-ut+w/2)^2+d^2}}\right\}$$

Types of electrodes

- Surface electrodes
- Needle electrodes
- Concentric needle electrodes
- Fine wire electrodes

Stimulation electrodes

- Short-term and long term stimulation
- Charge accumulation
    - Charge balancing of electrodes

End of Lecture